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THE DESIGN AND EVALUATION OF TRANSMIT AND RECEIVE ANTENNAS FOR AN IONOSPHERIC COMMUNICATIONS PROBE SYSTEM:
B. SLOPING-VEE BEAMS

by

Georgios Theodoros Bougioukos

December, 1992

Thesis Advisor: Richard W. Adler

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The purpose of this study was to design and evaluate the performance of a transmitting antenna for an HF communications probe system.

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A sloping-vee antenna was chosen for initial "shakedown" tests to support the transmitting requirements of the probe system at 5.6, 11, and 16.8 MHz. The Eyring Ground Measurement Probe was used to measure the ground constants at the NPS beach site. The Numerical Electromagnetics Code (NEC) was utilized to analyze the performance of the antenna at the NPS beach, and for average, poor, fair and arctic ground conditions.

The antenna provides a maximum gain of 1.46 dBi at 5.6 MHz, 5.56 dBi at 11 MHz, 8 dBi at 16.8 MHz, and positive gain at take-off angles

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The Design and Evaluation of Transmit and Receive Antennas for an Ionospheric Communications Probe System: B. Sloping-Vee Beams

by

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The antenna provides a maximum gain of 1.46 dBi at 5.6 MHz, 5.56 dBi at 11 MHz, 8 dBi at 16.8 MHz, and positive gain at take-off angles between 3° and 33° at frequencies from 5.6 to 16.8 MHz. The VSWRs with a standard 600 Ohm to 50 Ohm impedance matching transformer (12:1) are 1.73 at 5.6 MHz, 1.77 at 11 MHz, and 1.53 at 16.8 MHz.

ACKNOWLEDGEMENTS

I would like to dedicate this thesis in the memory of my parents Theodoros and Eleni Bougioukos.

I would also like to express my gratitude to Dr. Richard w. Adler, for his valuable guidance and assistance.

Finally, I wish to thank my uncles Nickolaos and Paraskeyi Bougioukos for their physiological support, and all the Greek tax-payers for having paid for my course of studies.

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I. INTRODUCTION

Long-distance communication at high frequencies (HF) is usually via ionospheric propagation. Transmitted waves at correct elevation angles refract from the ionosphere, depending on frequency and ionization levels, and hopefully bend downward and return to the earth.

The Navy needs accurate measurements of field strength for polar and equatorial ionospheric propagation. The Polar and Equatorial NVIS EXperimental (PENEX) project, is being conducted by a team assigned to develop all the required equipment for an HF ionospheric communication probe system. Cape Wales, AK, was chosen as the transmit site of the probe system, and Seattle, WA, San Diego, CA, State College, PA, and Fairbanks, AK, were chosen as the receive sites.

Monterey, CA, was selected as the transmit site, and San Diego, CA, was selected as the receive site of a near vertical incidence skywave (NVIS) communication path to test all the equipment involved in the PENEX project. The results of the tests will be used for the appropriate selection of equipment before the final installation and testing at the appropriate locations.

The purpose of this thesis is to design and evaluate the performance of a sloping-vee antenna to support the transmitting requirements of the PENEX project. The antenna is designed to provide at least 0 dBi gain at appropriate take-off angles for three distinct frequencies of 5.6, 11, and 16.8 MHz.

The sloping-vee antenna was modeled over the NPS beach ground and over fair, poor, average and arctic ground conditions to establish the sensitivity of the antenna relative to the site.

Chapter II lists all the parameters that are basic in the sloping-vee antenna design.

The performance of HF communications can be very dependent on characteristics of ground beneath the antenna. Chapter III describes the method and the procedure for the NPS beach ground constant measurements (average relative dielectric constant and conductivity), and the design procedure for the sloping-vee antenna.

Chapter IV contains a description of the Numerical Electromagnetics Code (NEC), and the sloping-vee antenna modeling procedure.

Chapter V includes the sloping-vee antenna performance over NPS beach ground and over fair, average, poor, and arctic ground conditions.

Finally, in Chapter VI, the results are summarized with conclusions and recommendations given regarding the design of the sloping-vee antenna.

II. BACKGROUND

A. LONG-WIRE ANTENNAS

Long-wire antennas are composed of long-wire radiators which are straight conductors from one to many wavelengths long. The current distributions on the wires may be standing waves (resonant antennas) or progressive waves (travelling-wave antennas) or a combination of both.

Radiation patterns of long-wire antennas are fairly complicated compared to simple loops and dipoles. The input impedance of resonant antennas is very dependent on frequency, resulting in narrow-band operation. The current distribution is a standing wave with sinusoidal variation. The antennas usually operate satisfactorily only at a particular frequency and various harmonics of that frequency.

Travelling-wave antennas are classed as " wide-band " because the input impedance is an acceptable value over a wide range of frequencies.

Long-wire antennas are often used in the HF band (2 to 30 MHz), and take the form of horizontal-rhombics, sloping-rhombics, horizontal-vees, vertical-vees, vertical inverted-vees and the sloping-vees.

B. THE SLOPING-VEE ANTENNA

The terminating sloping-vee antenna is a simple and easily erected antenna that provides useful directivity and gain for ionospheric paths greater than 500 miles at frequencies from 4 to 18 MHz [Ref. 1].

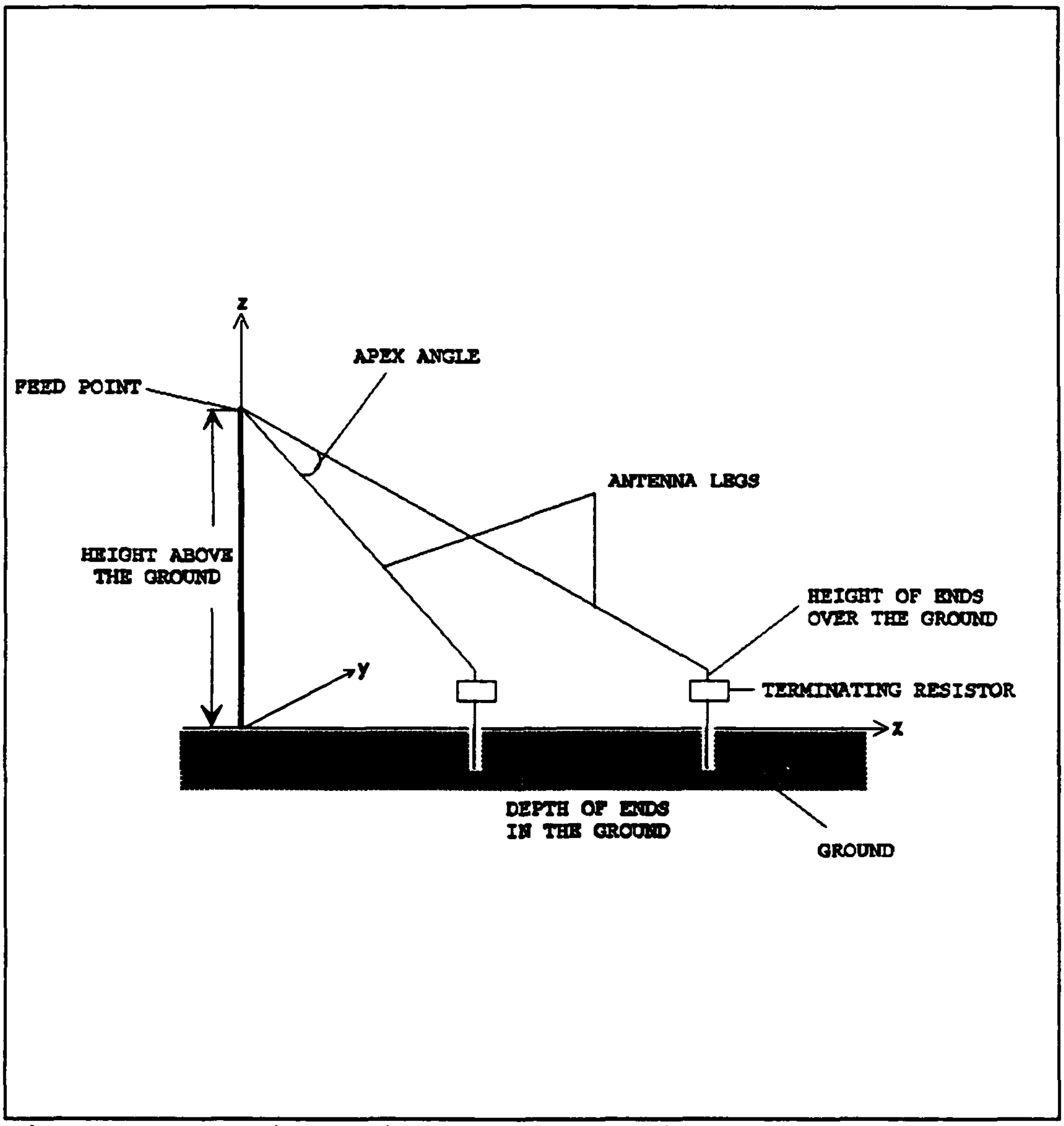

Figure 1. Configuration of the Sloping-Vee Antenna.

Three parameters are basic to all sloping-vee antennas [Ref. 2]. These are:

1. Leg length

As the leg length increases, the antenna's gain increases at a given operating frequency. When the leg length of a sloping-vee antenna is less than 2.0 to 2.5 wavelengths at the operating frequency, the antenna has essentially 0 dBi gain. Also, increasing the leg length has an effect on the angle at which the main lobe forms (i.e., the take-off angle). An antenna with short legs will have a higher take-off angle for a given operating frequency than an antenna with long legs.

2. Height above the ground

Increasing the frequency of operation makes the antenna's height above the ground greater in terms of wavelengths.

Increasing or decreasing the height of the terminating end of the sloping-vee antenna also has an effect on the take-off angle. The sleeper the slope, the closer to the antenna the ground reflection occurs, and a higher take-off angle will result.

3. Apex angle

Changing the apex angle of the sloping-vee antenna, while keeping the height above the ground and leg length constant, affects the gain. Generally, the smaller the apex angle, the greater the gain. This holds true down to about 30 degrees. For angles less than this, the gain decreases.

A terminating resistor in each leg of the sloping-vee antenna provides better radiation patterns. If the terminating resistors are removed, the two forward lobes will be matched by two rear lobes smaller in amplitude. The impedance will generally remain the same.

III. GROUND MEASUREMENTS AND SLOPING-VEE ANTENNA DESIGN

A. GROUND MEASUREMENTS

Ground measurements were taken at the NPS beach to determine the relative dielectric constant and conductivity of the ground from 5.6 to 16.8 MHz. The Eyring Ground Measurement Probe, P/N 200-4326, was used for the above procedure.

1. The Eyring Ground Measurement Probe

a. Introduction

The Eyring Ground Measurement Probe was designed to characterize the radio frequency properties of soils. The design and analysis approach was inspired by the published work of Longmire and Smith [Ref. 3], King and Smith [Ref. 4], and Smith and Norgard [Ref. 5]. The basic approach was developed under the Hardened Antenna Technology Program of the U.S.Air Force, and the hardware design and analysis have been developed by Communications Systems Division of Eyring.

The probe system, with five measurement depths, is designed for use with a network analyzer, HP 3577/A, for ground constant measurements from 1 to 50 MHz frequency range. A software package is available to support the calculation of relative dielectric constant ϵ_r (epsilon), conductivity σ (sigma), and skin depth over a range of frequencies or at a single frequency. Data logging and data analysis software is also available in conjunction with semi-automatic network analyzer control. It supports both single measurement and batch data reduction. The measurements made with the probe can be correlated with volumetric water content and Wenner array low frequency conductivity measurements (up to 100 Khz) to improve measurement confidence [Ref. 6].

b. Description

The ground measurement probe is an electrically short monopole which is mechanically designed to allow insertion into the ground as an inverted monopole. Figure 2 illustrates the complete ground probe measurement system.

The basic ground measurement probe assembly has five standard 0.625" diameter brass rods with 6.95", 12.95", 18.95", 24.95", and 30.95" lengths that penetrate 6", 12", 18", 24", and 30" into the ground respectively. A 6" probe is shown inserted in the ground with an exposed shaft and banana plug connector that mates with the coaxial adapter in Figure 3.

A computer is used to keep and analyze all the data from the ground measurement process. The main Broadband Antenna Test System (BATS) control program is the basic control program for the ground measurement system. It provides an interface to the entire BATS program as well as selected DOS commands. A subset of the BATS programs is also provided for the ground measurement system.

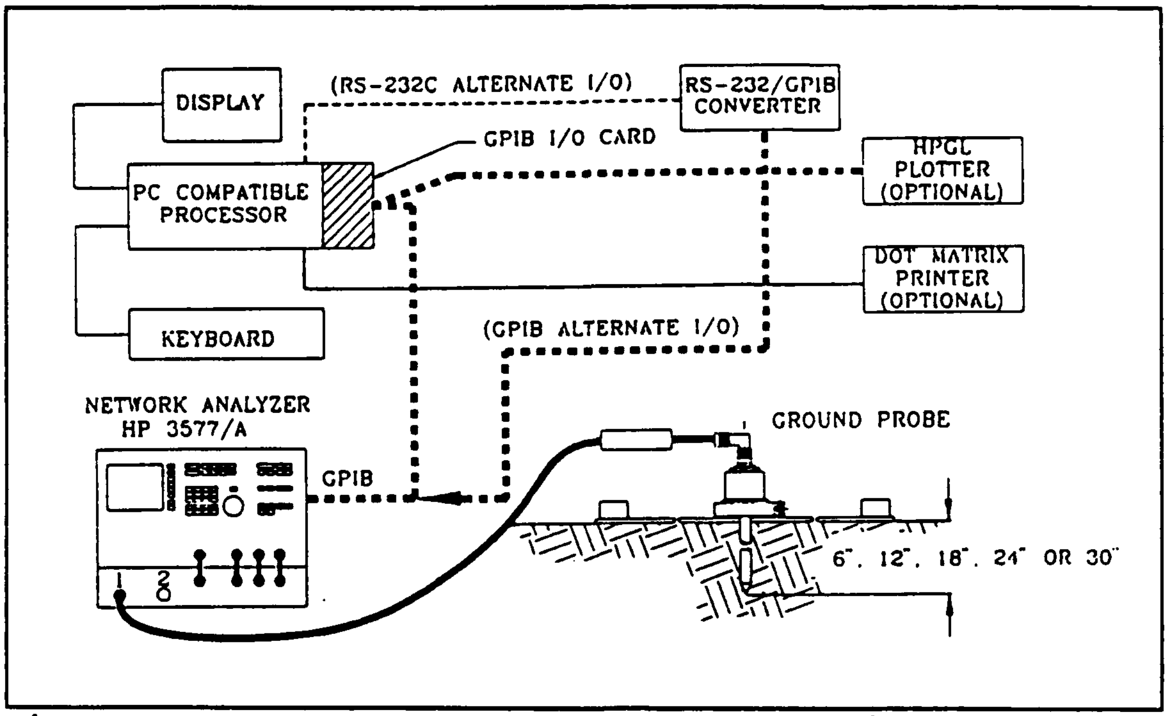

Figure 2. Ground Measurement Probe system with I/O options shown [From Ref. 6].

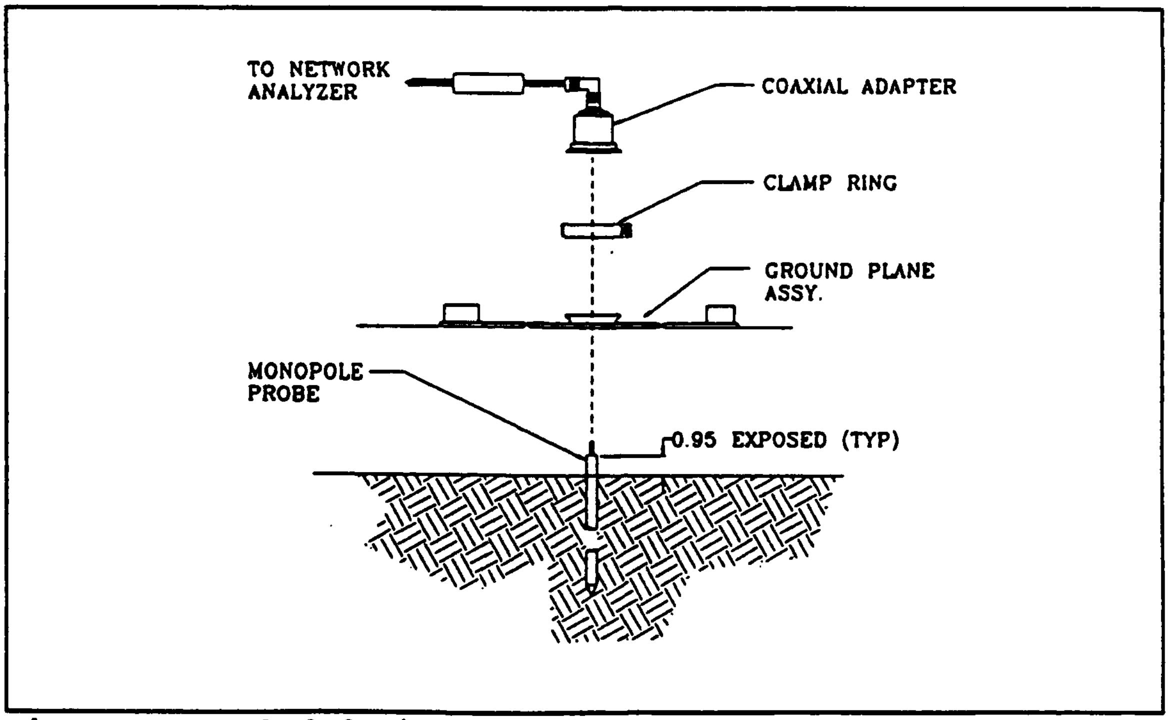

Figure 3. Exploded view of 6" ground measurement probe [From Ref. 6].

2. NPS Beach Ground Measurements

Three flat locations were selected at the NPS beach site for the ground constant measurements.

The ground measurements were taken with the 6", 12", 18", 24", and 30" probes as outlined in Figure 2. The data sets of the above measurements and the relative plots (relative dielectric constant and conductivity versus frequency), are included as site 1, site 2, and site 3 NPS beach ground measurements in Appendix A. The data sets were calculated and are illustrated (average relative dielectric constant and conductivity versus frequency) in Figures 4 - 6.

The average values of relative dielectric constant and conductivity versus frequency of the three locations were calculated and the results (average relative dielectric constant and conductivity versus frequency of ground at the NPS beach) are illustrated in Figure 7.

The average relative dielectric constant ϵ_r (epsilon) and conductivity σ (sigma) of the NPS beach ground at 5.6, 11, and 16.8 MHz are shown in Table 1.

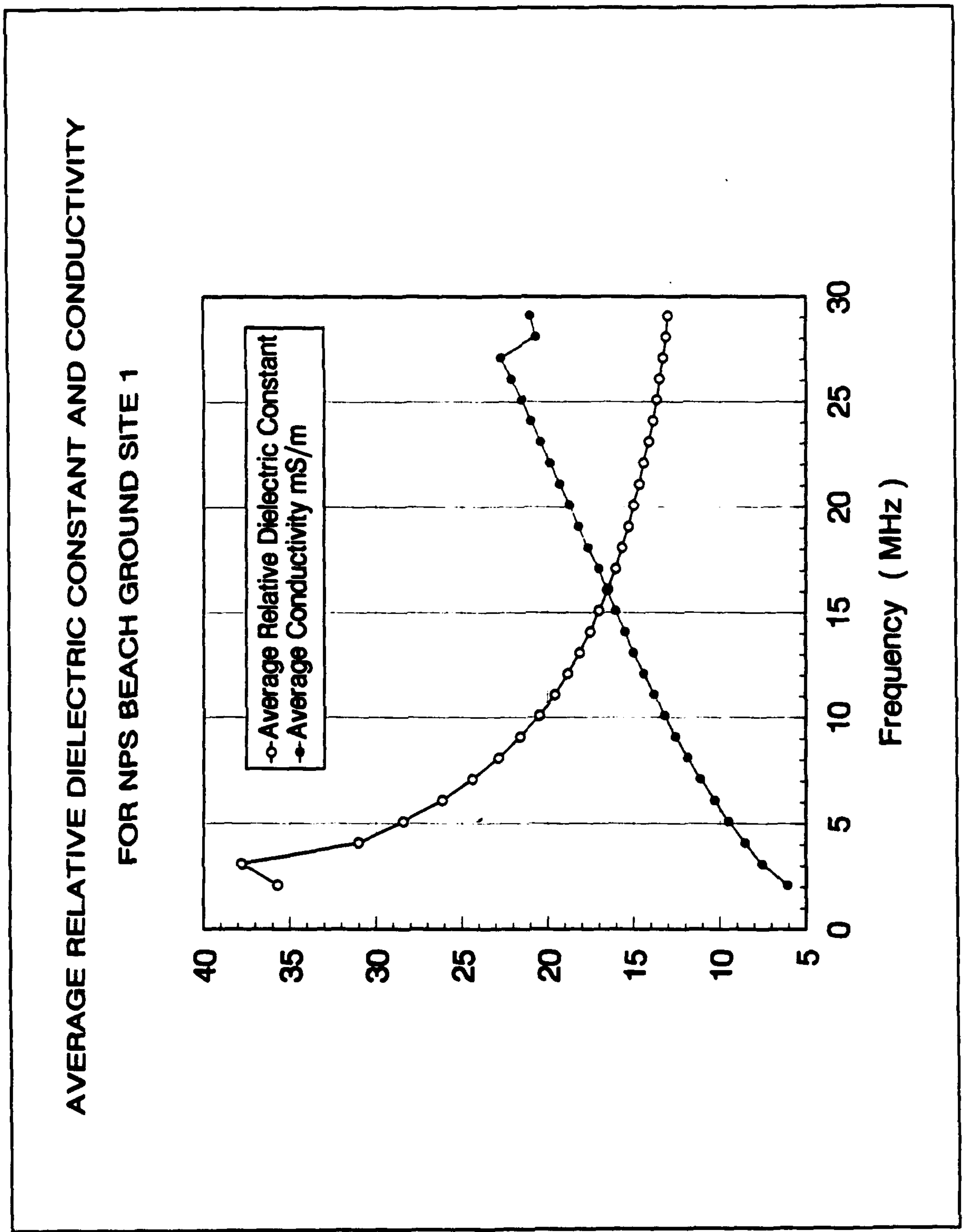

Figure 4. Average Relative Dielectric Constant and Conductivity for NPS Beach Site 1.

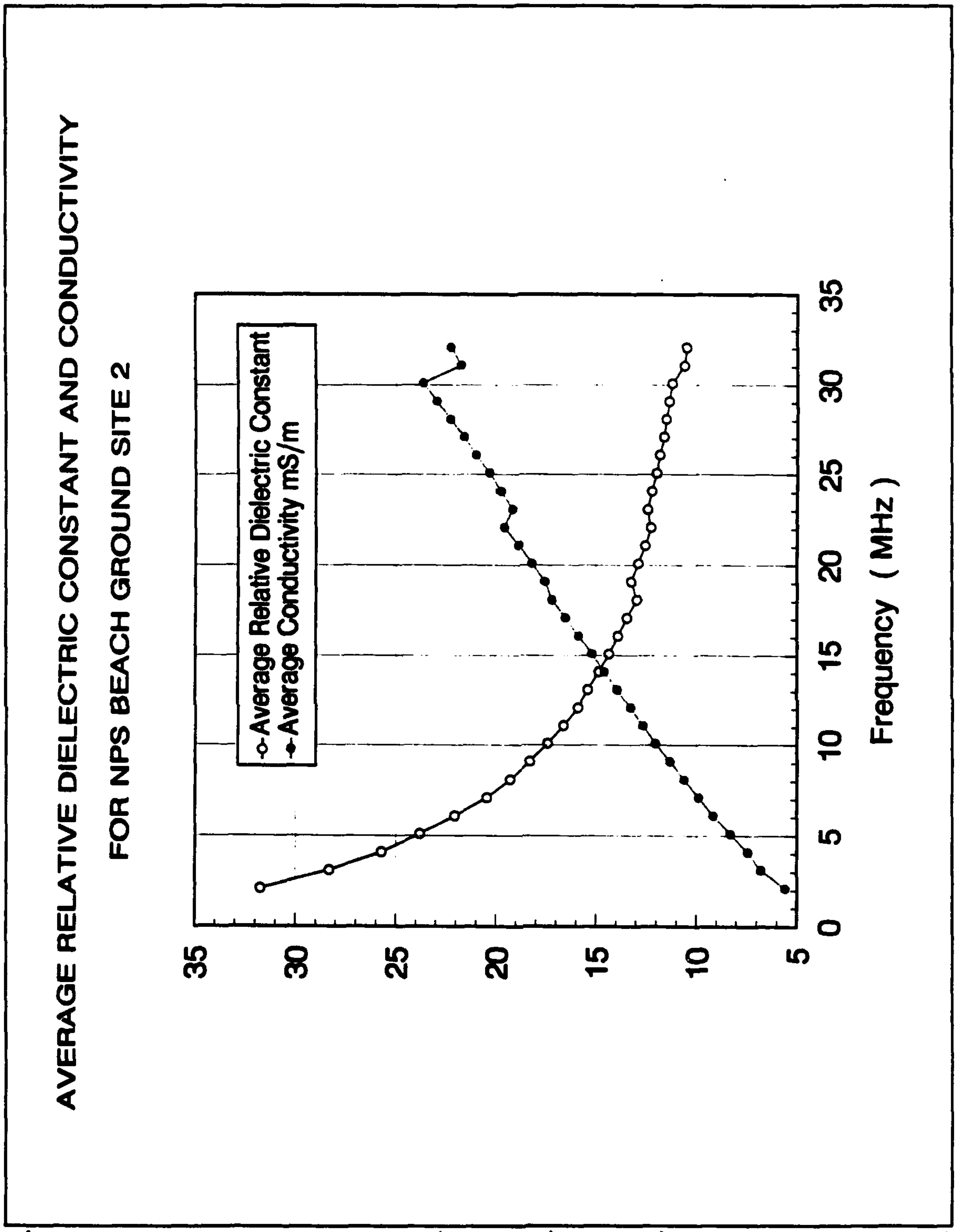

Figure 5. Average Relative Dielectric Constant and Conductivity for NPS Beach Site 2.

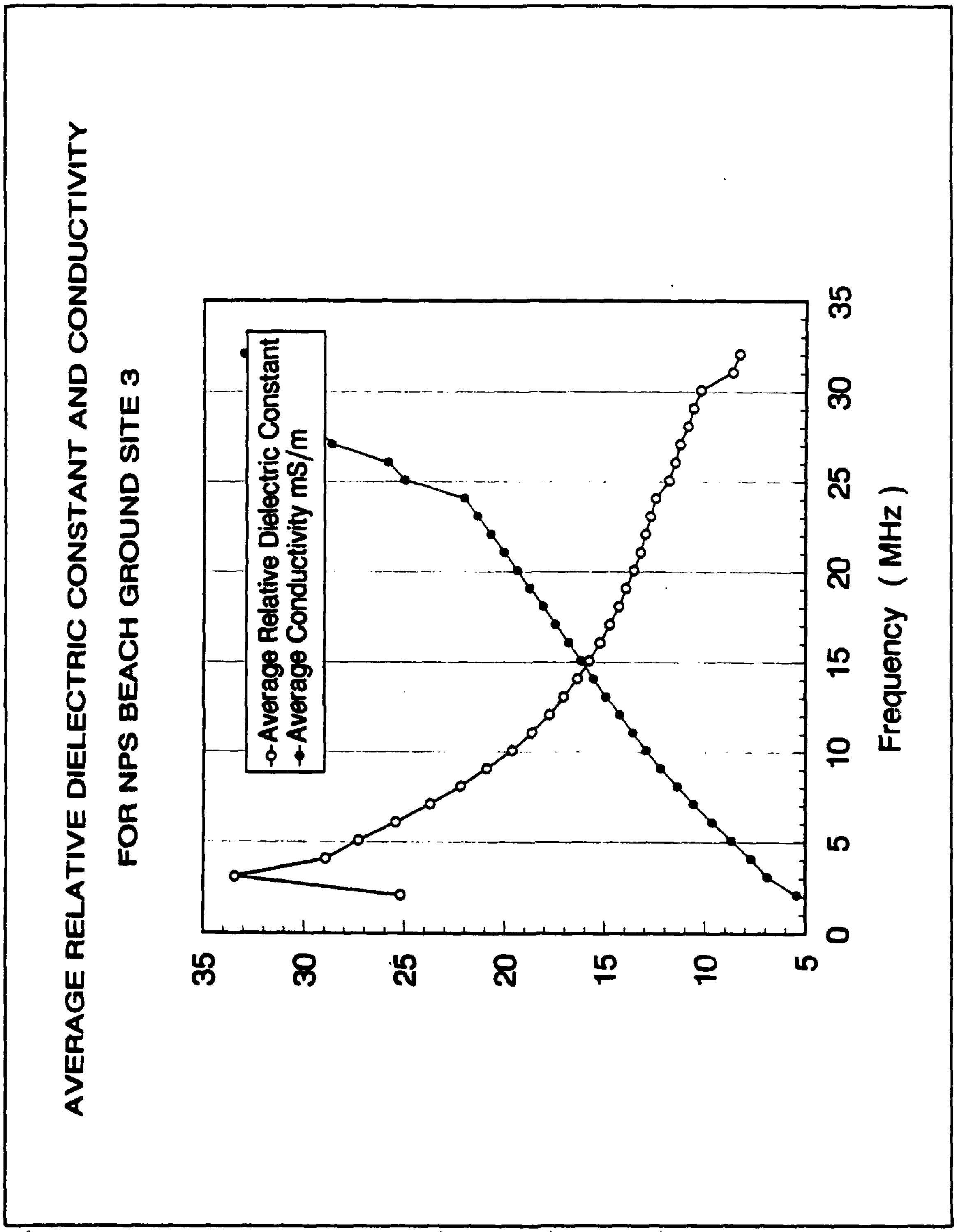

Figure 6. Average Relative Dielectric Constant and Conductivity for NPS Beach Site 3.

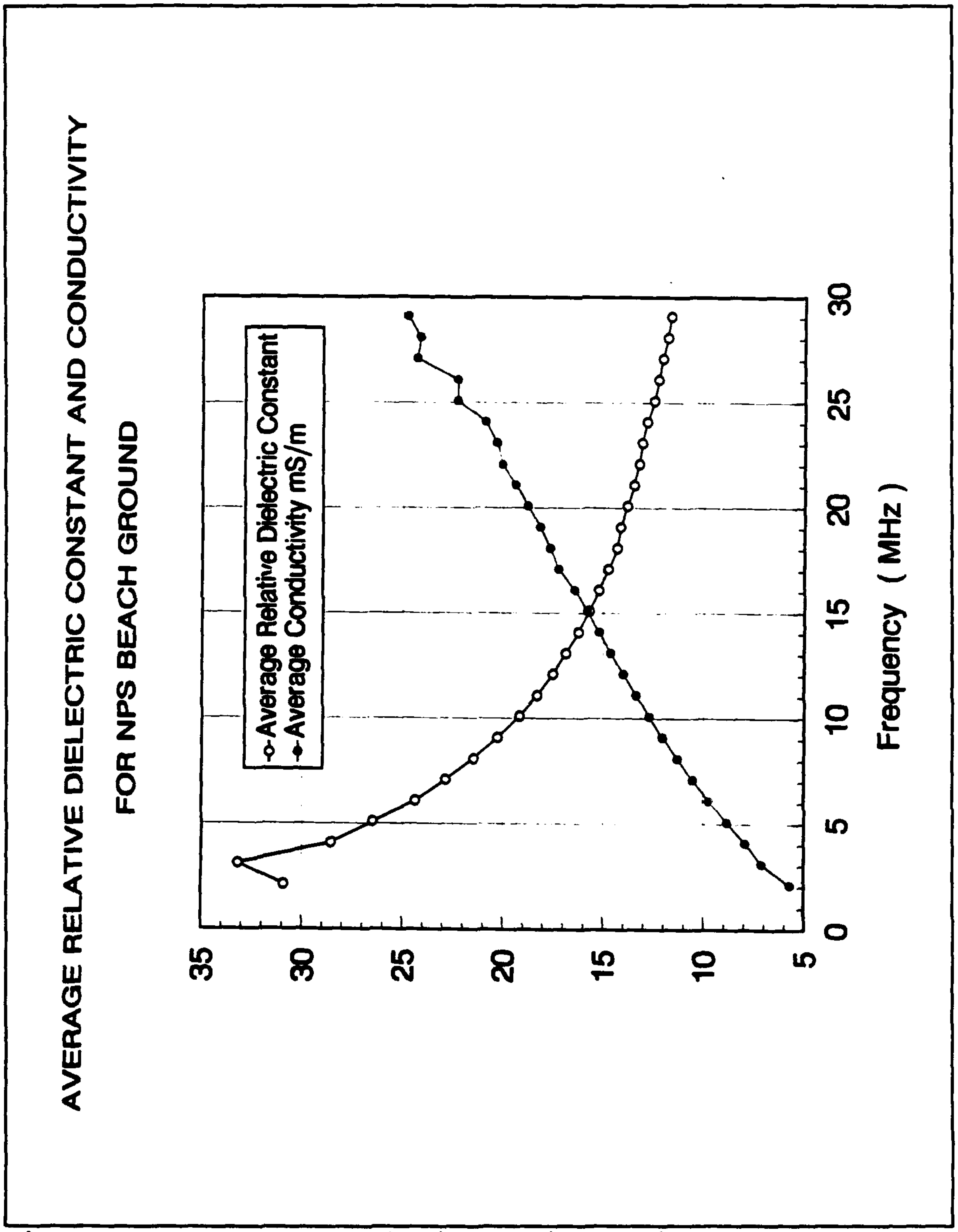

Figure 7. Average Relative Dielectric Constant and Conductivity for NPS Beach.

TABLE 1

AVERAGE RELATIVE DIELECTRIC CONSTANT AND CONDUCTIVITY FOR NPS BEACH GROUND

FREQUENCY (MHz)	RELATIVE DIELECTRIC CONSTANT	CONDUCTIVITY (mS/m)
5.6	25.5	0.009
11.0	18.3	0.013
16.8	14.6	0.016

B. SLOPING-VEE ANTENNA DESIGN

The sloping-vee antenna was designed to operate at 5.6, 11, and 16.8 MHz, over the NPS beach ground with relative dielectric constant and conductivity as shown in Table 1.

The sloping-vee antenna characteristics are:

- Height of center H=50 Ft
- Length of legs L=450 Ft
- Apex angle a=60 Deg
- Height of ends over the ground H_1=7 Ft
- Depth of ends in the ground H_2=2 Ft
- Terminating resistors R=450 Ohm
- Radius of the wires r=0.002 M.

The resistance of the terminating resistors was calculated from the NEC program as described in Chapter IV.

The configuration of the sloping-vee antenna that was designed is illustrated in Figure 8.

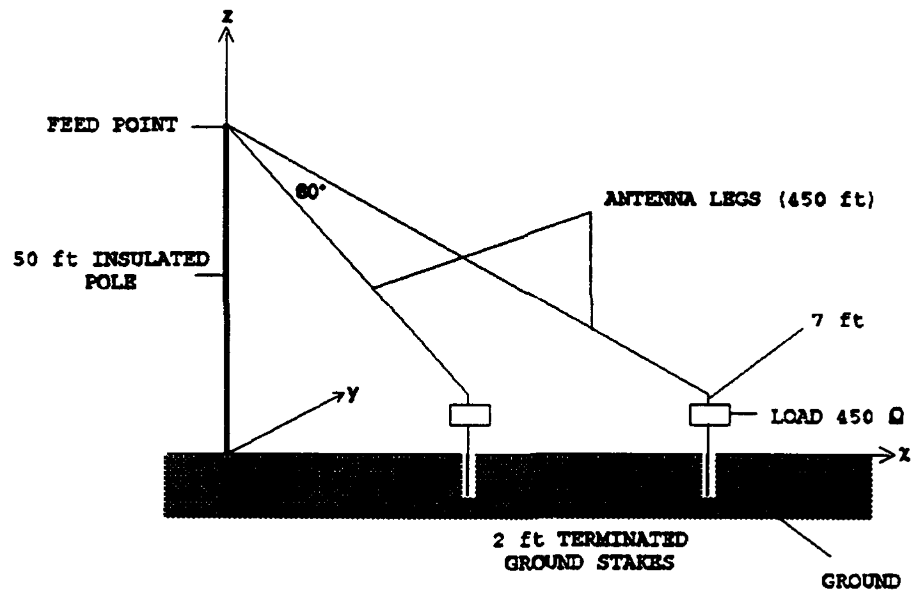

Figure 8. Configuration of the Designed Sloping-Vee Antenna.

IV. NEC DESCRIPTION AND SLOPING-VEE ANTENNA MODELING

A. THE NUMERICAL ELECTROMAGNETICS CODE

The NEC user-oriented computer code was designed for the analysis of the electromagnetic response of wire antennas and other metal structures [Ref. 7]. It uses a numerical solution to integral equations that describe the currents induced on the structure by local voltage sources on the structure or by an incident plane wave with either linear or elliptical polarization.

The code combines an integral equation for smooth surfaces with one specialized to wires to allow for convenient and accurate modeling of a wide range of structures. A model may entail nonradiating networks and transmission lines connecting parts of structure, perfect or imperfect conductors and lumped element loading. A structure may also be modeled over a ground plane that could be either a perfect or an imperfect conductor.

The excitation may be either voltage sources on the structure or an incident plane wave of linear or elliptic polarization. The output may include induced currents and charges, radiated fields, and near electric or magnetic fields. The program is suited to either antenna analysis or scattering and EMP studies.

The integral equation approach is most applicable to structures with dimensions up to several wavelengths. Although there is no theoretical size limit, the numerical solution requires a matrix equation of increasing order as the structure size is increased relative to wavelength. Due to this fact, more computer time and file storage may be required for modeling very large structures. Standard high-frequency approximations such as geometrical optics, physical optics or geometrical theory of diffraction may be more suitable in such cases than the integral equation approach used in NEC.

The code also contains a Numerical Green's Function for partitioned-matrix solution and a treatment for lossy grounds that is accurate for antennas very close to the ground surface.

Flat patches for surfaces and sort straight segments for wires are basic elements for modeling structures with the NEC code.

A wire segment is defined by the coordinates of its two end points and its radius. A wire antenna, as well as any other conducting object in its vicinity that affects its performance, must be modeled with strings of segments following the paths of the wires. The most critical step in obtaining accurate results is the proper choice of segmentation. The number of segments should be the minimum required for accuracy and efficient run time. Guidelines for choosing segments involving both geometrical and electrical factors are given below [REf. 7]:

- Geometrically, segments may not overlap and should follow the paths of conductors as closely as possible.
- Each wire has to be divided into segments of length Δ. Segment lengths(Δ) should be less than 0.1λ and greater than 0.001λ at the desired frequency of operation. Segments smaller than 0.001λ should be avoided.
- Short segments (0.05λ) or less may be needed at critical regions such us junctions or curves.
- The wire radius, α, relative to λ is limited by the kernel approximations used in the integral equation. The thin-wire kernel approximation requires $\Delta/\alpha>8$ for errors less than 1% and it is used at bends in wires. The extended thin-wire kernel approximation requires $\Delta/\alpha<2$ for the same accuracy as the thin-wire case, and it is used at segments connected in a strange line.
- A segment is required at each point where a voltage source or a network connection is located.
- A large radius change between connected segments may decrease accuracy, particularly with small Δ/α.
- Segments will be treated if the distance of their ends is less about 0.001 times the length of the shortest segment.
- Identical coordinates should be used for connected segment ends.
- If the segment length between two adjacent connected wires is different, the wires must be modeled using tapered segment lengths.

B. SLOPING-VEE ANTENNA MODELING

The sloping-vee antenna that was modeled has the shape and physical dimensions as described in Chapter III.

The segmentation was chosen according to NEC wire modeling guidelines. Tapered segment lengths for ends over and in the in the ground was selected because of the large difference between the length of the legs of the sloping-vee antenna and the lengths of the two ends.

The NEC-3, Sommerfeld-Norton method, was selected to analyze the effect of the ground on the antenna performance. The antenna was fed at the apex height, and four resistors (150, 300, 450, and 600 Ohms) were tested as terminating resistors.

All the data cards used to model this antenna over the NPS beach ground and over fair, average, poor, and arctic ground conditions are included in Appendix B.

V. SLOPING-VEE ANTENNA PERFORMANCE

A. SLOPING-VEE ANTENNA PERFORMANCE OVER NPS BEACH GROUND

The sloping-vee antenna was analyzed with 150, 300, 450, and 600 Ohm terminating resistors at 5.6, 11, and 16.8 MHz. Input impedance, average power gain, and normalized power gain are illustrated in Tables 2 - 4.

TABLE 2

SLOPING-VEE ANTENNA PARAMETERS

AT 5.6 MHz OVER NPS BEACH GROUND

EPSILON=25.5 / SIGMA=0.009 mS/m

TERMINATIONS (Ohm)	Z_{in} (Ohm)	P_{Aver}	GAIN (dBi)
150	679.32+j285.06	0.332	1.60
300	886.36+j154.08	0.324	1.45
450	1040.96+j 15.89	0.339	1.46
600	1154.46-j118.41	0.340	1.54

TABLE 3

SLOPING-VEE ANTENNA PARAMETERS

AT 11 MHz OVER NPS BEACH GROUND

EPSILON=18.3 / SIGMA=0.013 mS/m

TERMINATIONS (Ohm)	Z_{in} (Ohm)	P_{Aver}	GAIN (dBi)
150	650.70+j348.50	0.569	5.68
300	839.60+j269.10	0.556	5.55
450	993.70+j190.03	0.561	5.56
600	1120.70+j114.10	0.572	5.62

TABLE 4

SLOPING-VEE ANTENNA PARAMETERS

AT 16.8 MHz OVER NPS BEACH GROUND

EPSILON=14.6 / SIGMA=0.016 mS/m

TERMINATIONS (Ohm)	Z_{in} (Ohm)	P_{Aver}	GAIN (dBi)
150	1218.76-j236.52	0.749	8.23
300	975.18-j206.94	0.730	8.06
450	831.74-199.45	0.731	8.00
600	737.54-j198.49	0.741	8.00

Based on the results of the total impedance, and given the fact that the antenna structure will be fed through a transmission line with characteristic impedance of 50 Ohms, four transformers (2:1, 4:1, 6:1, 12:1) were used in order to solve the matching problem. The voltage standing wave ratios (VSWR) were computed by using the formulas [Ref.8]:

$$VSWR=\frac{1+|\overline{\Gamma}_L|}{1-|\overline{\Gamma}_L|} \tag{1}$$

$$\overline{\Gamma}_L=\frac{Z_L-Z_0}{Z_L+Z_0} \tag{2}$$

where:

$\overline{\Gamma}_L$ =reflection coefficient

Z_L =input impedance of the sloping-vee antenna

Z_0 =characteristic impedance of the transmission line.

The VSWRs of the sloping-vee antenna with 150, 300, 450, and 600 Ohm terminating resistors at 5.6, 11, and 16.8 MHz are illustrated in Tables 5 - 8 respectively. The corresponding plots of the frequency versus VSWR in each case are shown in Figures 9 - 12.

The best VSWR was obtained with 300 Ohm terminating resistors. The 450 Ohm resistors gave better radiation patterns, because the two forward lobes were matched by two smaller rear lobes than for the 300 Ohm resistors.

TABLE 5

VSWR FOR SLOPING-VEE ANTENNA WITH 150 Ohm TERMINATIONS

FREQUENCY TRANSFORMER	5.6 MHz	11 MHz	16.8 MHz
50 Ohm	15.98	16.76	25.29
100 Ohm	8.01	8.40	12.64
200 Ohm	4.04	4.25	6.32
400 Ohm	2.11	2.26	3.17
600 Ohm	1.58	1.74	2.13

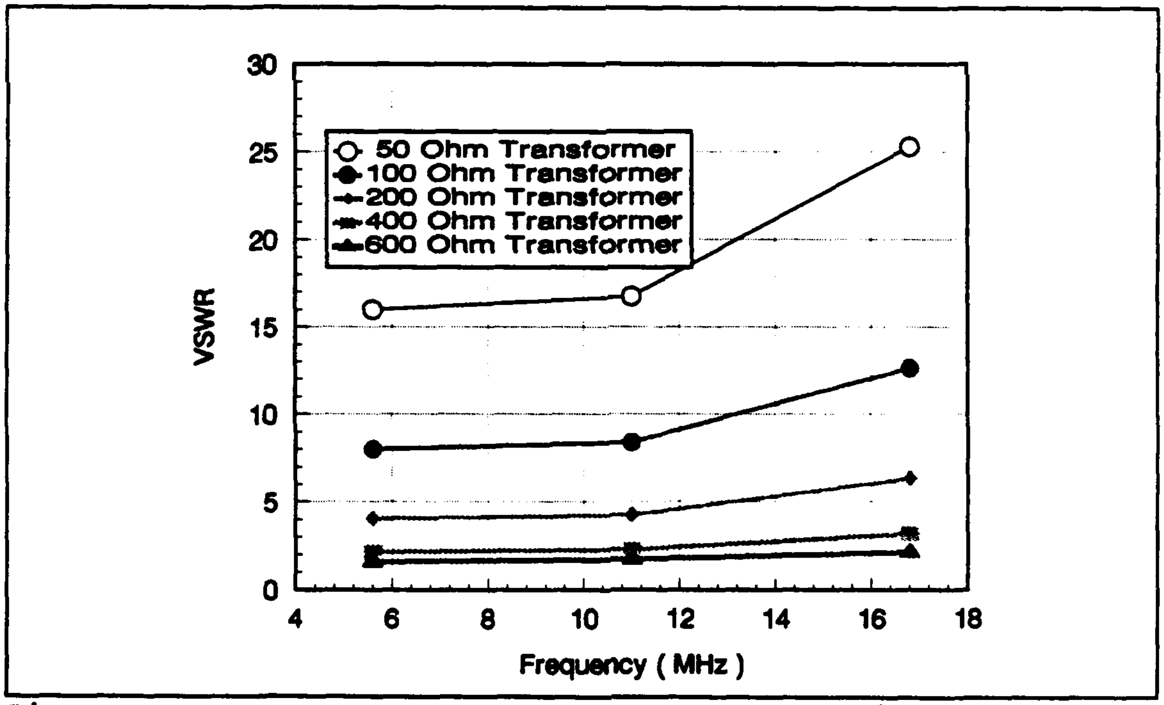

Figure 9. VSWR versus Frequency plot for Sloping-Vee Antenna with 150 Ohm terminations.

TABLE 6

VSWR FOR SLOPING-VEE ANTENNA WITH 300 Ohm TERMINATIONS

FREQUENCY / TRANSFORMER	5.6 MHz	11 MHz	16.8 MHz
50 Ohm	18.26	18.52	20.38
100 Ohm	9.13	9.26	10.19
200 Ohm	4.57	4.65	5.10
400 Ohm	2.29	2.36	2.56
600 Ohm	1.55	1.65	1.73

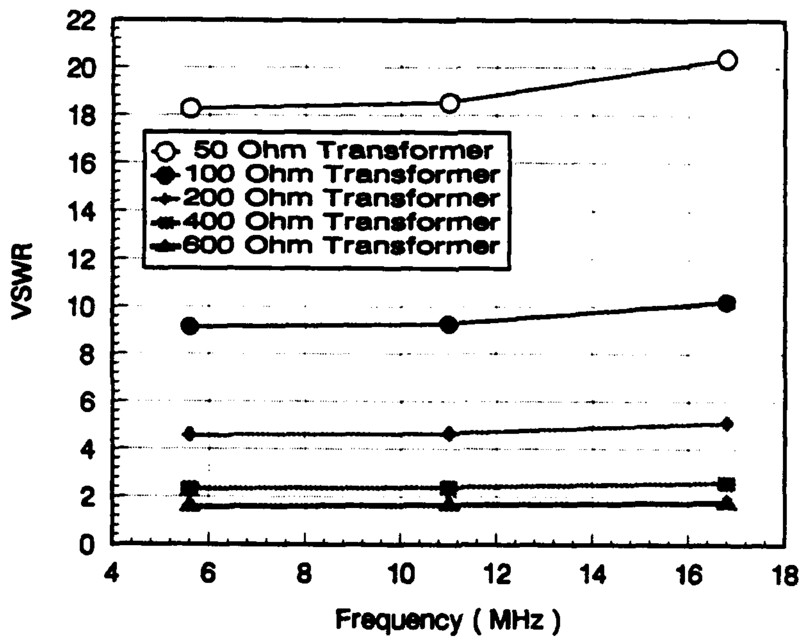

Figure 10. VSWR versus Frequency plot for Sloping-Vee Antenna with 300 Ohm terminations.

TABLE 7

VSWR FOR SLOPING-VEE ANTENNA WITH 450 Ohm TERMINATIONS

FREQUENCY / TRANSFORMER	5.6 MHz	11 MHz	16.8 MHz
50 Ohm	20.82	20.60	17.59
100 Ohm	10.41	10.30	8.80
200 Ohm	5.20	5.15	4.41
400 Ohm	2.60	2.59	2.23
600 Ohm	1.73	1.74	1.53

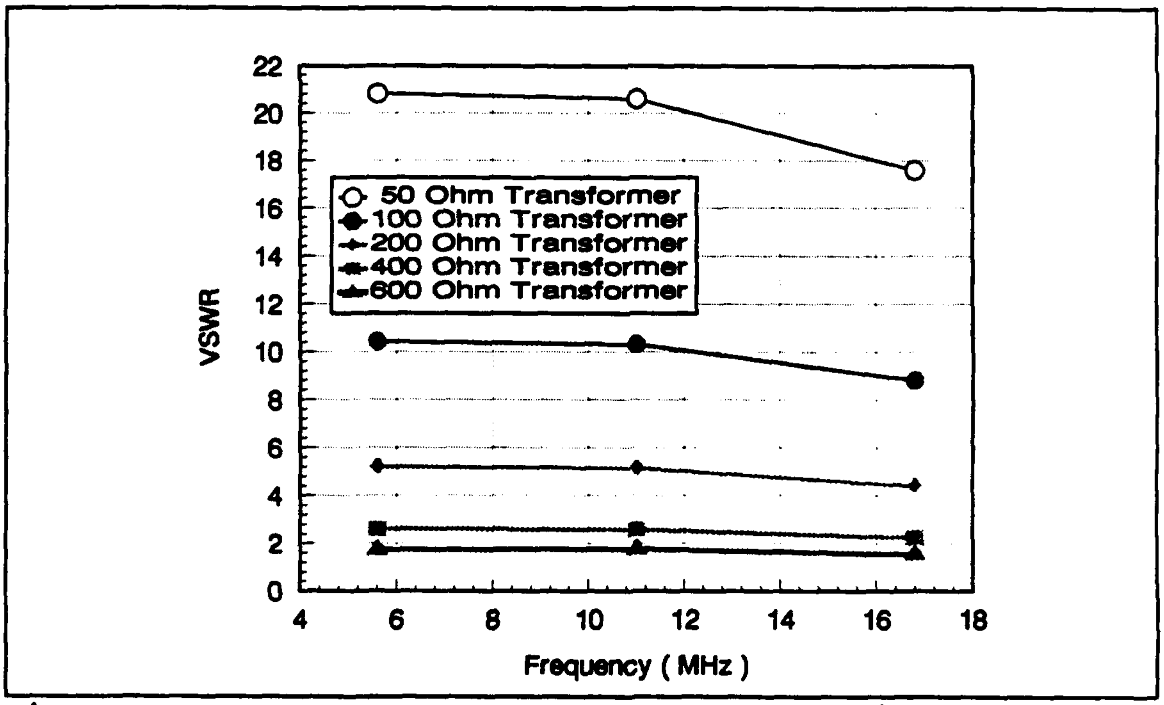

Figure 11. VSWR versus Frequency plot for Sloping-Vee Antenna with 450 Ohm terminations.

TABLE 8

VSWR FOR SLOPING-VEE ANTENNA WITH 600 Ohm TERMINATIONS

FREQUENCY / TRANSFORMER	5.6 MHz	11 MHz	16.8 MHz
50 Ohm	23.33	22.64	15.82
100 Ohm	11.66	11.32	7.91
200 Ohm	5.83	5.66	3.97
400 Ohm	2.92	2.83	2.02
600 Ohm	1.95	1.89	1.43

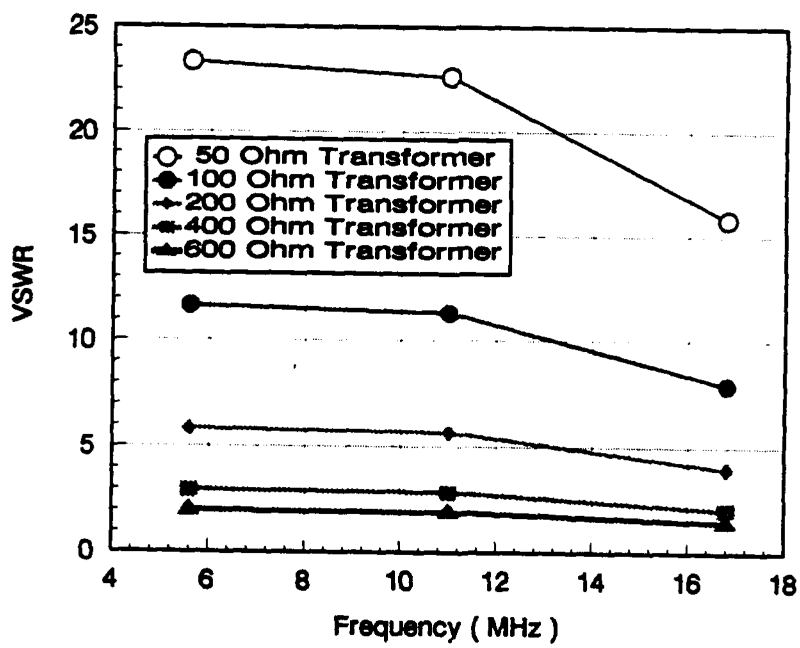

Figure 12. VSWR versus Frequency plot for Sloping-Vee Antenna with 600 Ohm terminations.

Comparison of VSWRs with radiation patterns indicated that the best design for the NPS beach location was the sloping-vee antenna with 450 Ohm resistors matched to a 50 Ohm characteristic impedance transmission line, via a 600 Ohm (12:1) impedance transformer. Values of the VSWR are summarized in Table 9.

TABLE 9

VSWR FOR THE SLOPING-VEE ANTENNA OVER NPS BEACH GROUND

FREQUENCY	5.6 MHz	11 MHz	16.8 MHz
VSWR	1.73	1.74	1.53

Examples of the radiation patterns are shown in Figures 13 - 18. The complete set of radiation patterns is included in Appendix C.

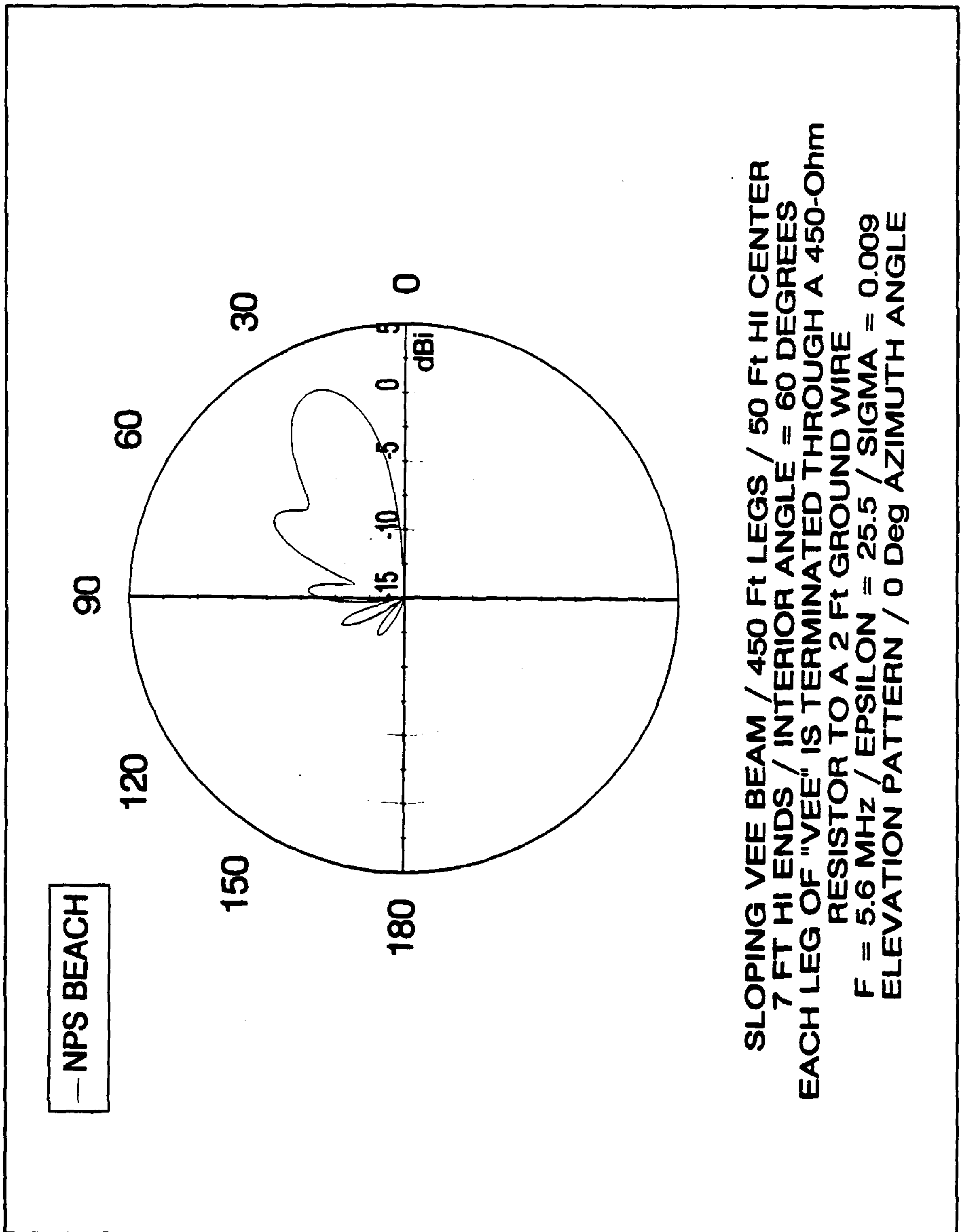

Figure 13. Sloping-Vee Beam Elevation Radiation Pattern ($\phi=0°$), over the NPS Beach ground at 5.6 MHz.

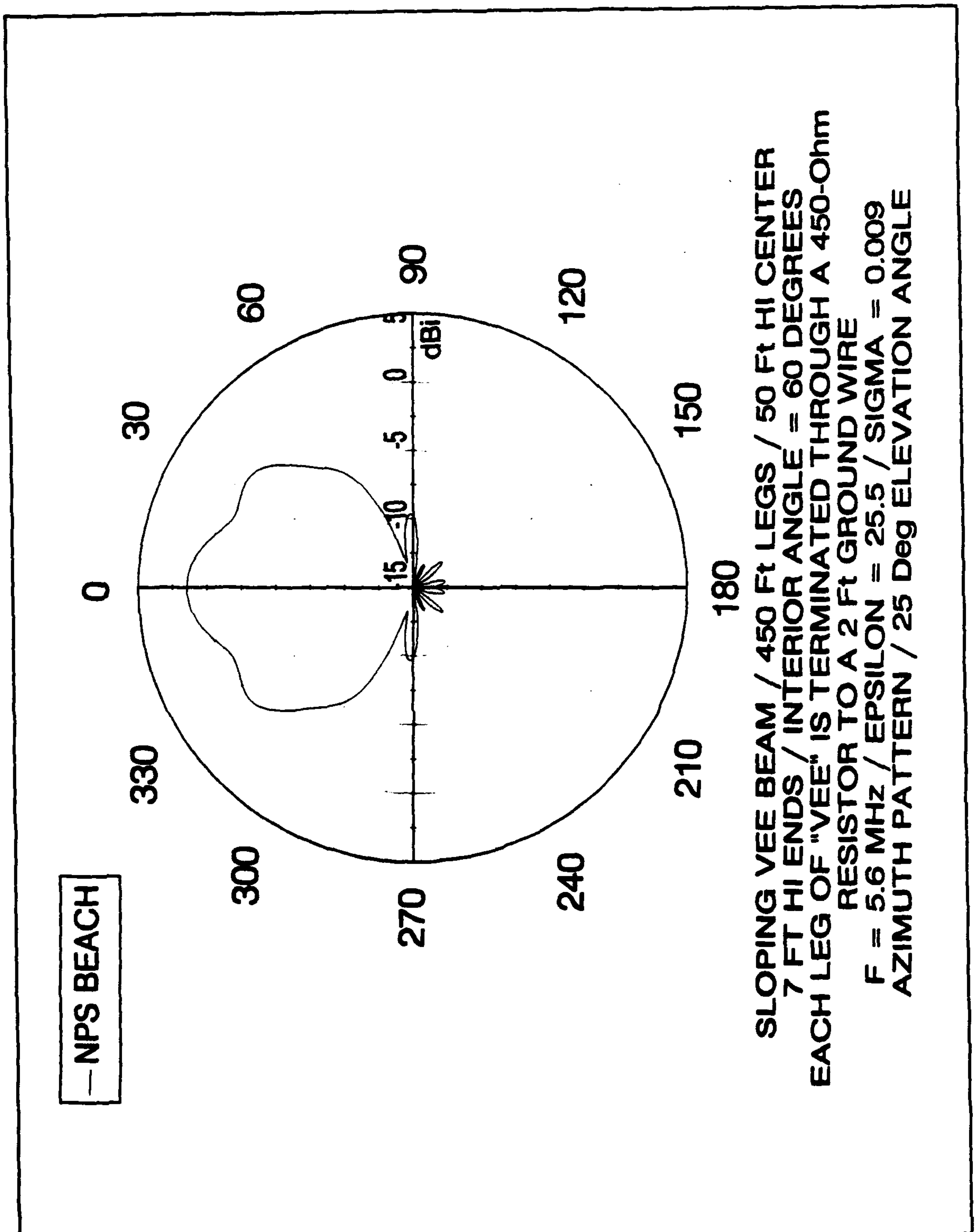

Figure 14. Sloping-Vee Beam Azimuth Radiation Pattern ($\theta=65°$), over the NPS Beach Ground at 5.6 MHz.

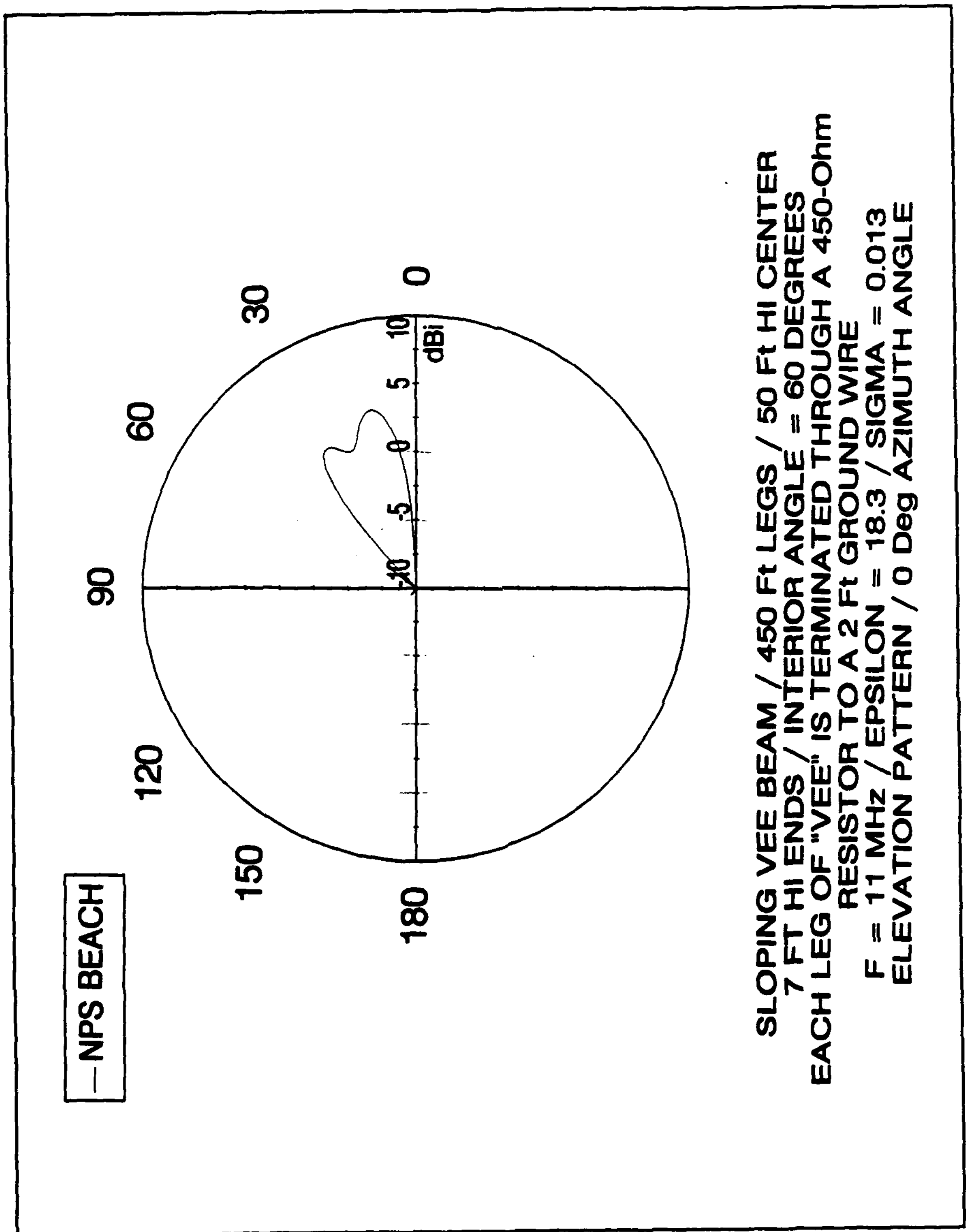

Figure 15. Sloping-Vee Beam Elevation Radiation Pattern (ϕ=0°), over the NPS Beach Ground at 11 MHz.

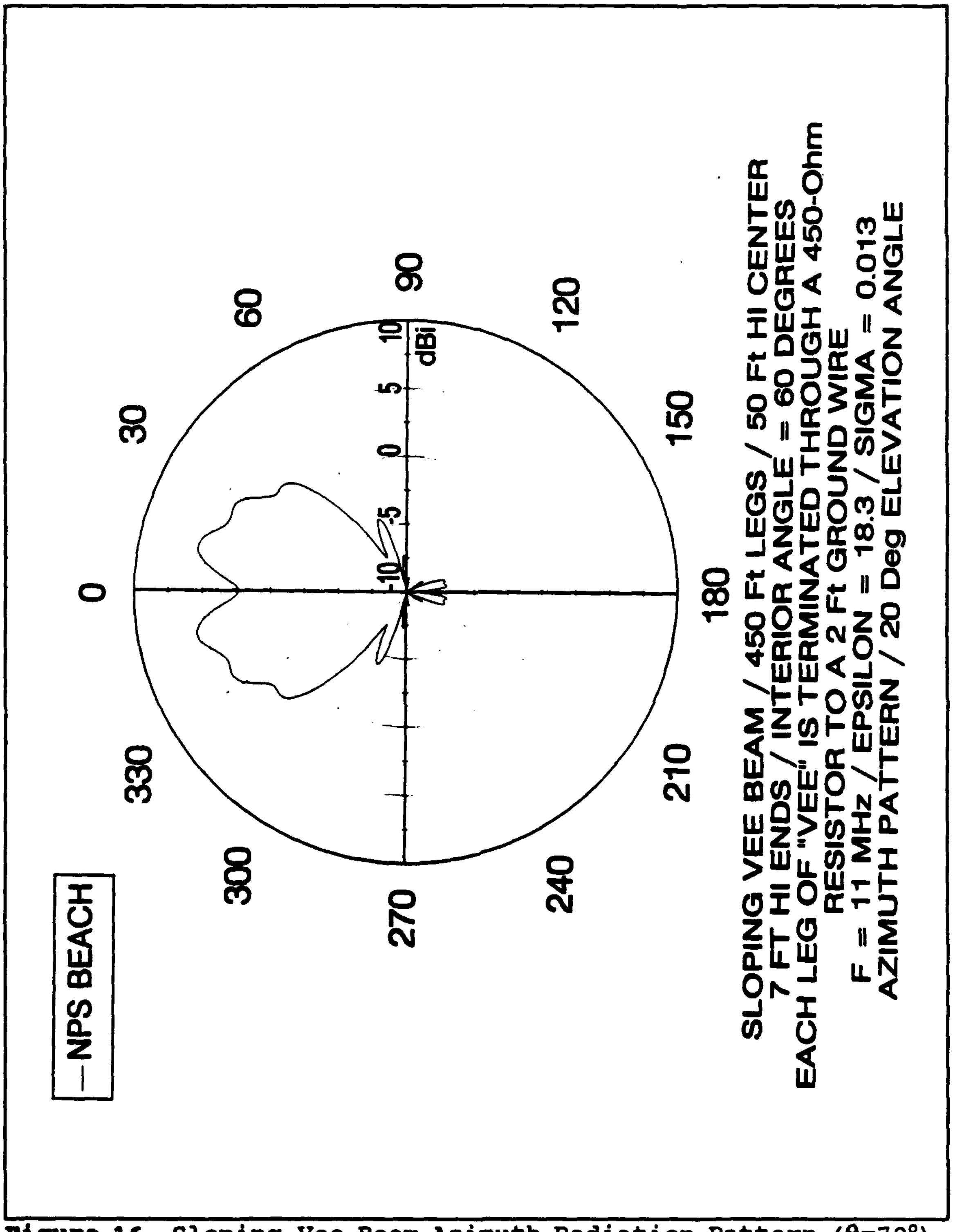

Figure 16. Sloping-Vee Beam Azimuth Radiation Pattern (θ=70°), over the NPS Beach Ground at 11 MHz.

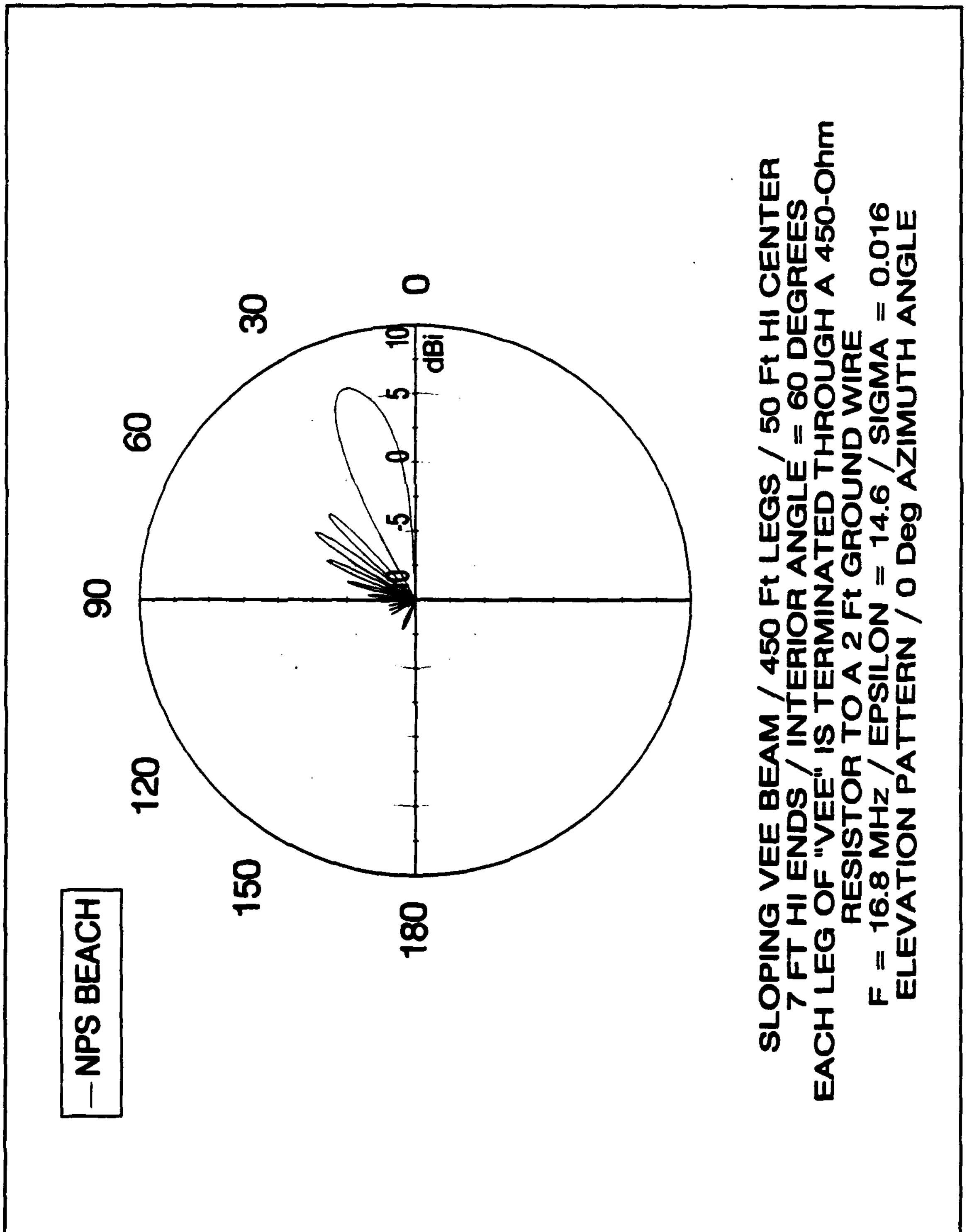

Figure 17. Sloping-Vee Beam Elevation Radiation Pattern (ϕ=0°), over the NPS Beach Ground at 16.8 MHz.

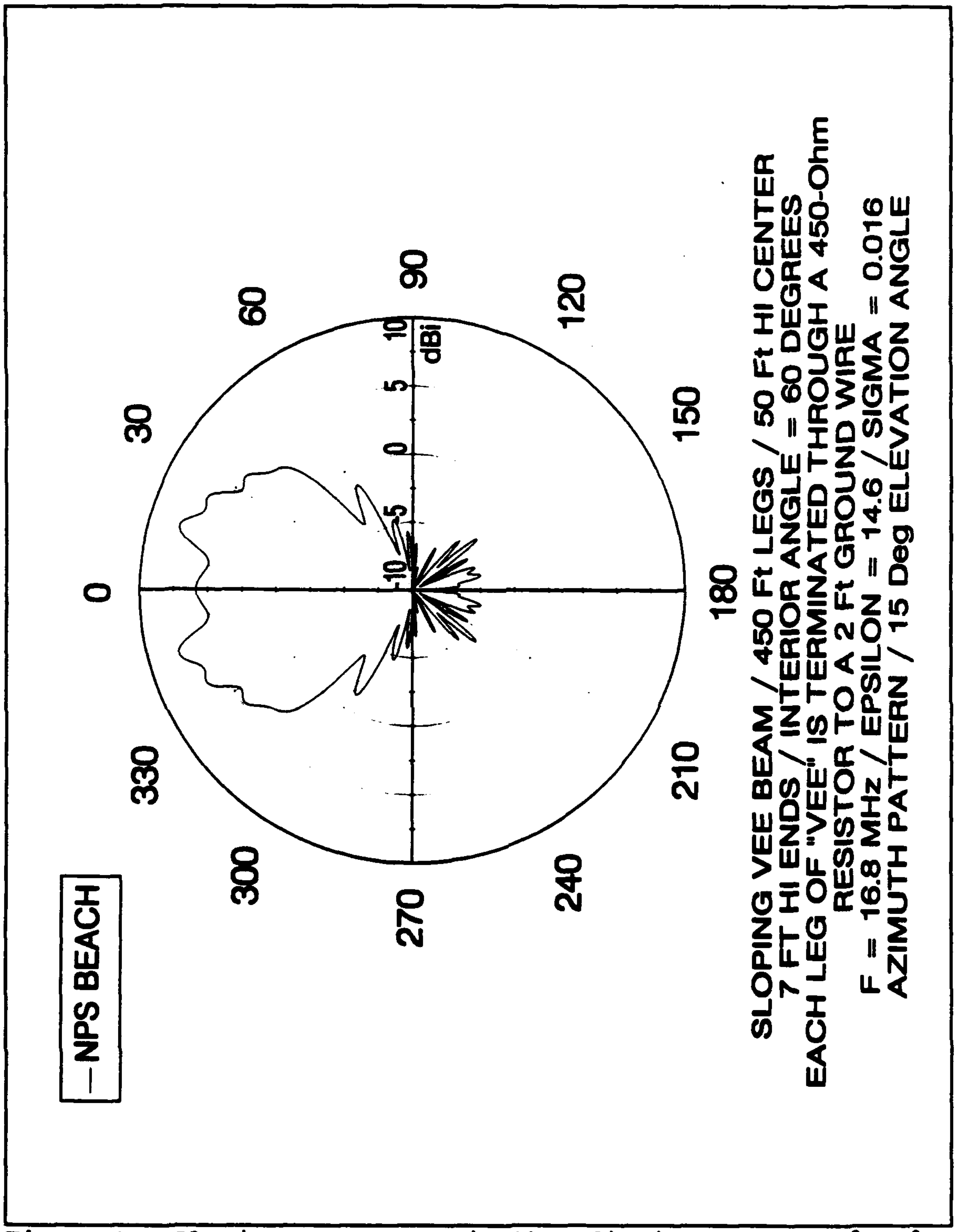

Figure 18. Sloping-Vee Beam Azimuth Radiation Pattern (θ=75°), over the NPS Beach Ground at 16.8 MHz.

B. SLOPING-VEE ANTENNA PERFORMANCE OVER FAIR , AVERAGE AND POOR GROUND CONDITIONS

The sloping-vee antenna with 450 Ohm resistors was also analyzed over fair, average, and poor ground conditions. This was done to better understand the difference in the antenna performance for conditions other than the NPS beach ground. The relative dielectric constant and conductivity of fair, average, and poor ground conditions are shown in Table 10.

TABLE 10

FAIR , AVERAGE AND POOR GROUND MEASUREMENTS

GROUND	FREQUENCY (MHz)	RELATIVE DIELECTRIC CONSTANT	CONDUCTIVITY (mS/m)
FAIR	5.6 11.0 16.8	12.0	0.005
AVERAGE	5.6 11.0 16.8	10.0	0.003
POOR	5.6 11.0 16.8	5.0	0.001

Input impedance, average power gain, and normalized power gain, are illustrated in Table 11.

The VSWRs were calculated with a standard 600 to 50 Ohm impedance matching transformer (12:1). These calculations are summarized in Tables 12 - 14.

TABLE 11

SLOPING-VEE ANTENNA PARAMETERS

OVER FAIR , AVERAGE AND POOR GROUND

FREQUENCY (MHz)	GROUND	Z_{in} (Ohm)	P_{Aver}	GAIN (dBi)
5.6	FAIR	1059.90-j 90.25	0.339	1.35
	AVERAGE	1008.44-j159.60	0.334	1.11
	POOR	950.32-j356.72	0.345	1.09
11	FAIR	968.44+j108.19	0.529	5.34
	AVERAGE	949.02+j 67.32	0.514	5.21
	POOR	935.30-j 75.89	0.493	5.01
16.8	FAIR	849.80-j132.37	0.676	7.70
	AVERAGE	848.46-j101.10	0.661	7.60
	POOR	786.52-j 9.96	0.635	7.34

TABLE 12

VSWR FOR SLOPING-VEE ANTENNA AT 5.6 MHz

OVER FAIR , AVERAGE AND POOR GROUND

GROUND	VSWR WITH 600 Ohm TRANSFORMER
FAIR	1.78
AVERAGE	1.74
POOR	1.91

TABLE 13

VSWR FOR SLOPING-VEE ANTENNA AT 11 MHz

OVER FAIR , AVERAGE AND POOR GROUND

GROUND	VSWR WITH 600 Ohm TRANSFORMER
FAIR	1.64
AVERAGE	1.59
POOR	1.57

TABLE 14

VSWR FOR SLOPING-VEE ANTENNA AT 16.8MHz

OVER FAIR , AVERAGE AND POOR GROUND

GROUND	VSWR WITH 600 Ohm TRANSFORMER
FAIR	1.48
AVERAGE	1.45
POOR	1.31

C. SLOPING-VEE ANTENNA PERFORMANCE OVER ARCTIC GROUND CONDITIONS

The sloping-vee antenna with 450 Ohm resistors was also analyzed over arctic ground conditions to examine the antenna performance at the Cape Wales ground. The relative dielectric constant, and conductivity of arctic ground are shown in Table 15.

Input impedance, average power gain, and normalized power gain are provided in Table 16. The VSWRs were calculated with a standard 600 to 50 Ohm impedance matching transformer (12:1), and the results are summarized in Tables 17 - 19.

TABLE 15

ARCTIC GROUND CONSTANTS

FREQUENCY (MHz)	GROUND	RELATIVE DIELECTRIC CONSTANT	CONDUCTIVITY (mS/m)
5.6	WET	55.0	0.017
	DRY	20.0	0.005
	FROZEN	12.0	0.002
11	WET	40.0	0.018
	DRY	16.0	0.006
	FROZEN	8.7	0.002
16.8	WET	33.0	0.021
	DRY	11.0	0.006
	FROZEN	7.0	0.003

TABLE 16

SLOPING-VEE ANTENNA PARAMETERS OVER ARCTIC GROUND

FREQUENCY (MHz)	GROUND	Z_{in} (Ohm)	P_{Aver}	GAIN (dBi)
5.6	WET	1037.32+j 87.97	0.326	1.61
	DRY	1015.18-j 37.87	0.324	1.26
	FROZEN	934.58-j160.11	0.312	0.72
11	WET	971.94+j234.46	0.561	5.49
	DRY	963.22+j142.94	0.532	5.34
	FROZEN	949.84+j 44.22	0.511	5.19
16.8	WET	858.26-j231.92	0.737	7.99
	DRY	834.42-j140.95	0.688	7.78
	FROZEN	811.68-j 76.34	0.661	7.61

TABLE 17

VSWR FOR SLOPING-VEE ANTENNA AT 5.6 MHz

OVER ARCTIC GROUND

GROUND	VSWR WITH 600 Ohm TRANSFORMER
WET	1.74
DRY	1.69
FROZEN	1.60

TABLE 18

VSWR FOR SLOPING-VEE ANTENNA AT 11 MHz

OVER ARCTIC GROUND

GROUND	VSWR WITH 600 Ohm TRANSFORMER
WET	1.76
DRY	1.66
FROZEN	1.58

TABLE 19

VSWR FOR SLOPING-VEE ANTENNA AT OF 16.8 MHz

OVER ARCTIC GROUND

GROUND	VSWR WITH 600 Ohm TRANSFORMER
WET	1.61
DRY	1.46
FROZEN	1.36

D. ANALYSIS OF THE RESULTS

The elevation and azimuth radiation patterns of the sloping-vee antenna over the NPS beach ground at 5.6, 11, and 16.8 MHz are as expected from long wire antenna theory [Ref. 2]. Input impedance, gain and VSWR calculated with a standard 600 to 50 Ohm impedance matching transformer (12:1) are summarized in Table 20.

TABLE 20

SLOPING-VEE ANTENNA PARAMETERS OVER NPS BEACH GROUND

FREQUENCY (MHz)	Z_{in} (Ohm)	GAIN (dBi)	VSWR WITH 600 Ohm TRANSFORMER
5.6	1040.96+j 15.89	1.46	1.73
11.0	993.70+j190.06	5.56	1.77
16.8	831.74-j199.45	8.00	1.53

At 5.6 MHz, the antenna provides a positive gain at elevation angles ($\phi=0°$) between 16° and 33°. The maximum gain (1.46 dBi) occurs at 25°.

At 11 MHz, a positive gain occurs at elevation angles ($\phi=0°$) between 17° and 38° and the maximum gain (5.56 dBi) occurs at 20°.

At 16.8 MHz, the antenna provides the largest gain (8 dBi) at 14° elevation angle. Positive gain occurs between 3° and 27°.

Input impedance, gain, and VSWR (with a standard 600 to 50 Ohm matching transformer) for the four ground conditions are similar to the corresponding values over the NPS beach ground.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The numerical analysis of the sloping-vee antenna has shown that the designed model can be used as a receiving or transmitting antenna over the NPS beach ground and over fair, poor, average and arctic ground conditions at 5.6, 11, and 16.8 MHz.

The antenna meets the requirement for gain greater than 0 dBi from 5.6 to 16.8 MHz. The construction of the antenna is simple, requiring only one support pole, but it does require a large amount of land area for its long legs.

Specific observations are:

1. The legs of the antenna were chosen to be 450 ft for operation at the desired frequencies.

2. The terminating resistor in each leg was selected to be 450 Ohm for two reasons. The two forward lobes were matched by two smaller rear lobes, and the VSWR with a standard 600 to 50 Ohm transformer is below 1.75 (1.73 at 5.6 MHz, 1.74 at 11 MHz, and 1.53 at 16.8 MHz).

3. The 60 degree apex angle in conjunction with the apex height of 50 ft provides the maximum gain at the three operating frequencies.

B. RECOMMENDATIONS

This antenna is not recommended for a communication link between Monterey, CA, and San Diego, CA because the required take-off angles are between 5° and 60°, and the antennas performance is limited to 3° to 33°.

The antenna's performance should be evaluated to determine applicability for use between the other sites involved in the PENEX project.

The termination height above the ground was modeled between 2 ft and 20 ft, and was chosen to be 7 ft for optimum performance. The examination of the influence on the antenna performance if the termination height is raised to a height above 20 ft is recommended.

Before a decision to use the antenna is made, a version should be constructed and VSWR measured and compared to the corresponding values calculated with NEC.

APPENDIX A. NPS BEACH GROUND MEASUREMENTS DATA SETS

A. SITE 1 GROUND MEASUREMENTS

6" Probe GNT , Cutoff Frequency = 132.53 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	49.6	8.79	1.52	5.05	142.93	17.10
3.10	45.7	10.93	1.39	3.83	96.82	12.30
4.10	38.5	12.35	1.41	3.12	73.21	10.11
5.10	34.0	13.64	1.41	2.65	58.85	8.63
6.10	30.4	14.75	1.43	2.33	49.20	7.62
7.10	27.7	15.72	1.44	2.09	42.27	6.85
8.10	25.4	16.59	1.45	1.90	37.06	6.25
9.10	23.7	17.37	1.45	1.75	32.98	5.77
10.10	22.2	18.03	1.45	1.63	29.72	5.37
11.09	20.9	18.72	1.45	1.53	27.04	5.03
12.09	19.9	19.35	1.45	1.44	24.81	4.74
13.09	19.0	19.90	1.44	1.36	22.91	4.48
14.09	18.1	20.44	1.44	1.30	21.29	4.26
15.09	17.4	20.97	1.43	1.24	19.88	4.06
16.09	16.8	21.46	1.43	1.19	18.64	3.88
17.09	16.2	21.91	1.42	1.14	17.55	3.73
18.09	15.7	22.38	1.42	1.10	16.58	3.58
19.09	15.2	22.87	1.42	1.06	15.71	3.45
20.09	14.8	23.28	1.41	1.02	14.93	3.33
21.09	14.4	23.72	1.41	0.99	14.23	3.21
22.09	14.0	24.19	1.41	0.96	13.58	3.11
23.09	13.6	24.60	1.41	0.93	12.99	3.02
24.09	13.3	25.06	1.41	0.90	12.45	2.92
25.09	13.0	25.50	1.40	0.88	11.96	2.84
26.09	12.8	25.91	1.39	0.85	11.50	2.76
27.09	12.5	26.31	1.39	0.83	11.08	2.68
28.09	12.3	26.73	1.39	0.81	10.68	2.61
29.09	12.1	27.11	1.38	0.79	10.31	2.55
30.09	11.9	27.48	1.38	0.77	9.97	2.49
31.08	11.7	27.87	1.38	0.76	9.65	2.43
32.08	11.5	28.26	1.38	0.74	9.35	2.37

12" Probe GNT , Cutoff Frequency = 40.08 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	45.3	8.20	1.55	5.20	142.93	17.81
3.10	47.1	10.45	1.29	4.00	96.82	12.31
4.10	40.2	11.75	1.28	3.28	73.21	10.08

5.10	36.6	13.07	1.26	2.81	58.85	8.52
6.10	33.4	14.27	1.26	2.46	49.20	7.45
7.10	30.9	15.39	1.26	2.19	42.27	6.66
8.10	28.8	16.40	1.27	1.99	37.06	6.04
9.10	27.0	17.34	1.27	1.82	32.98	5.55
10.10	25.5	18.20	1.27	1.69	29.72	5.15
11.09	24.3	19.03	1.27	1.57	27.04	4.80
12.09	23.2	19.89	1.28	1.47	24.81	4.50
13.09	22.3	20.69	1.28	1.39	22.91	4.24
14.09	21.4	21.47	1.28	1.31	21.29	4.02
15.09	20.7	22.25	1.28	1.24	19.88	3.82
16.09	20.0	23.06	1.29	1.18	18.64	3.64
17.09	19.4	23.86	1.29	1.13	17.55	3.47
18.09	18.8	24.64	1.30	1.07	16.58	3.33
19.09	18.3	25.46	1.31	1.03	15.71	3.19
20.09	17.8	26.31	1.32	1.98	14.93	3.07
21.09	17.4	27.15	1.33	1.94	14.23	2.96
22.09	17.0	28.02	1.34	1.90	13.58	2.85
23.09	16.5	28.93	1.36	1.87	12.99	2.76
24.09	16.2	29.81	1.37	1.83	12.45	2.66
25.09	15.9	30.75	1.39	1.80	11.96	2.58
26.09	15.6	31.73	1.41	1.77	11.50	2.50
27.09	15.3	32.68	1.42	1.74	11.08	2.42
28.09	15.0	33.77	1.44	1.71	10.68	2.35
29.09	14.7	34.83	1.47	1.69	10.31	2.29
30.09	14.4	35.92	1.49	1.66	9.97	2.22
31.08	14.0	36.92	1.52	1.64	9.65	2.17
32.08	13.8	38.19	1.55	1.62	9.35	2.11

18" Probe GNT , Cutoff Frequency = 27.59 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	36.6	6.52	1.53	5.86	142.93	19.89
3.10	38.0	8.15	1.24	4.58	96.82	13.78
4.10	32.9	9.18	1.22	3.77	73.21	11.23
5.10	30.4	10.21	1.18	3.24	58.85	9.45
6.10	28.2	11.17	1.17	2.85	49.20	8.22
7.10	26.4	12.13	1.17	2.53	42.27	7.31
8.10	24.8	13.00	1.16	2.29	37.06	6.61
9.10	23.5	13.90	1.17	2.09	32.98	6.04
10.10	22.3	14.69	1.17	1.93	29.72	5.58
11.09	21.4	15.49	1.17	1.79	27.04	5.19
12.09	20.5	16.31	1.18	1.66	24.81	4.85
13.09	19.7	17.12	1.19	1.56	22.91	4.56
14.09	19.1	17.91	1.20	1.47	21.29	4.31
15.09	18.4	18.74	1.21	1.38	19.88	4.08
16.09	17.9	19.59	1.23	1.30	18.64	3.88
17.09	17.3	20.51	1.24	1.23	17.55	3.70
18.09	16.9	21.43	1.26	1.16	16.58	3.54
19.09	16.4	22.35	1.28	1.10	15.71	3.39

20.09	16.0	23.34	1.31	1.05	14.93	3.25
21.09	15.5	24.42	1.34	0.99	14.23	3.12
22.09	15.2	25.50	1.37	0.94	13.58	3.00
23.09	14.8	26.68	1.40	0.89	12.99	2.89
24.09	14.4	27.97	1.45	0.85	12.45	2.79
25.09	14.1	29.28	1.49	0.81	11.96	2.69
26.09	13.7	30.73	1.54	0.76	11.50	2.61
27.09	13.3	32.32	1.62	0.72	11.08	2.52

24" Probe GNT , Cutoff Frequency = 30.09 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	25.5	4.00	1.34	7.75	142.93	24.48
3.10	26.4	4.87	1.07	6.22	96.82	16.98
4.10	23.5	5.50	1.03	5.17	73.21	13.69
5.10	22.2	6.10	1.97	4.48	58.85	11.43
6.10	20.9	6.69	1.94	3.96	49.20	9.88
7.10	19.8	7.28	1.93	3.53	42.27	8.74
8.10	18.9	7.78	1.91	3.22	37.06	7.86
9.10	18.0	8.32	1.91	2.94	32.98	7.16
10.10	17.3	8.78	1.90	2.73	29.72	6.59
11.09	16.7	9.22	0.89	2.55	27.04	6.11
12.09	16.2	9.67	0.89	2.39	24.81	5.70
13.09	15.7	10.09	0.88	2.25	22.91	5.35
14.09	15.3	10.50	0.88	2.14	21.29	5.04
15.09	15.0	10.91	0.87	2.03	19.88	4.77
16.09	14.6	11.30	0.86	1.94	18.64	4.52
17.09	14.4	11.72	0.86	1.85	17.55	4.30
18.09	14.1	12.10	0.85	1.77	16.58	4.10
19.09	13.9	12.55	0.85	1.70	15.71	3.92
20.09	13.7	12.96	0.85	1.63	14.93	3.75
21.09	13.6	13.37	0.84	1.57	14.23	3.60
22.09	13.5	13.75	0.83	1.52	13.58	3.45
23.09	13.4	14.11	0.82	1.48	12.99	3.31
24.09	13.4	14.52	0.81	1.43	12.45	3.18
25.09	13.4	14.84	0.79	1.40	11.96	3.06
26.09	13.5	15.15	0.78	1.37	11.50	2.95
27.09	13.6	15.44	0.76	1.34	11.08	2.83
28.09	13.6	15.75	0.74	1.32	10.68	2.73
29.09	13.8	15.92	0.72	1.31	10.31	2.63

31" Probe GNT , Cutoff Frequency = 30.09 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	21.6	2.87	1.14	9.65	142.93	27.41
3.10	22.0	3.45	0.91	7.83	96.82	19.04
4.10	20.0	3.93	0.86	6.51	73.21	15.21
5.10	18.9	4.37	0.82	5.65	58.85	12.66
6.10	17.9	4.78	0.79	5.01	49.20	10.91

7.10	17.1	5.17	0.77	4.52	42.27	9.62
8.10	16.4	5.54	0.75	4.12	37.06	8.63
9.10	15.8	5.87	0.74	3.81	32.98	7.84
10.10	15.2	6.17	0.72	3.55	29.72	7.20
11.09	14.8	6.44	0.71	3.34	27.04	6.67
12.09	14.4	6.68	0.69	3.17	24.81	6.22
13.09	14.0	6.89	0.68	3.03	22.91	5.83
14.09	13.7	7.10	0.66	2.90	21.29	5.49
15.09	13.4	7.27	0.65	2.80	19.88	5.19
16.09	13.2	7.43	0.63	2.71	18.64	4.92
17.09	12.9	7.55	0.61	2.64	17.55	4.68
18.09	12.8	7.66	0.60	2.58	16.58	4.46
19.09	12.6	7.74	0.58	2.53	15.71	4.26
20.09	12.5	7.78	0.56	2.50	14.93	4.08
21.09	12.4	7.77	0.54	2.48	14.23	3.92
22.09	12.2	7.73	0.51	2.48	13.58	3.77
23.09	12.1	7.61	0.49	2.50	12.99	3.63
24.09	12.0	7.46	0.46	2.53	12.45	3.51
25.09	11.9	7.24	0.44	2.59	11.96	3.39
26.09	11.8	6.99	0.41	2.66	11.50	3.29
27.09	11.6	6.68	0.38	2.76	11.08	3.19
28.09	11.4	6.35	0.36	2.87	10.68	3.11
29.09	11.2	5.99	0.33	3.01	10.31	3.04

Key:

MHZ =Frequency (Mhz)
Er =Effective Relative Permittivity
mS/m =Effective Conductivity (milli-Seimens/meter)
D.F =Dissipation Factor (Loss Tangent)
S.D =Skin Depth (meters)
W air =Wavelength in air (meters)
W gnd =Wavelength in ground (meters)

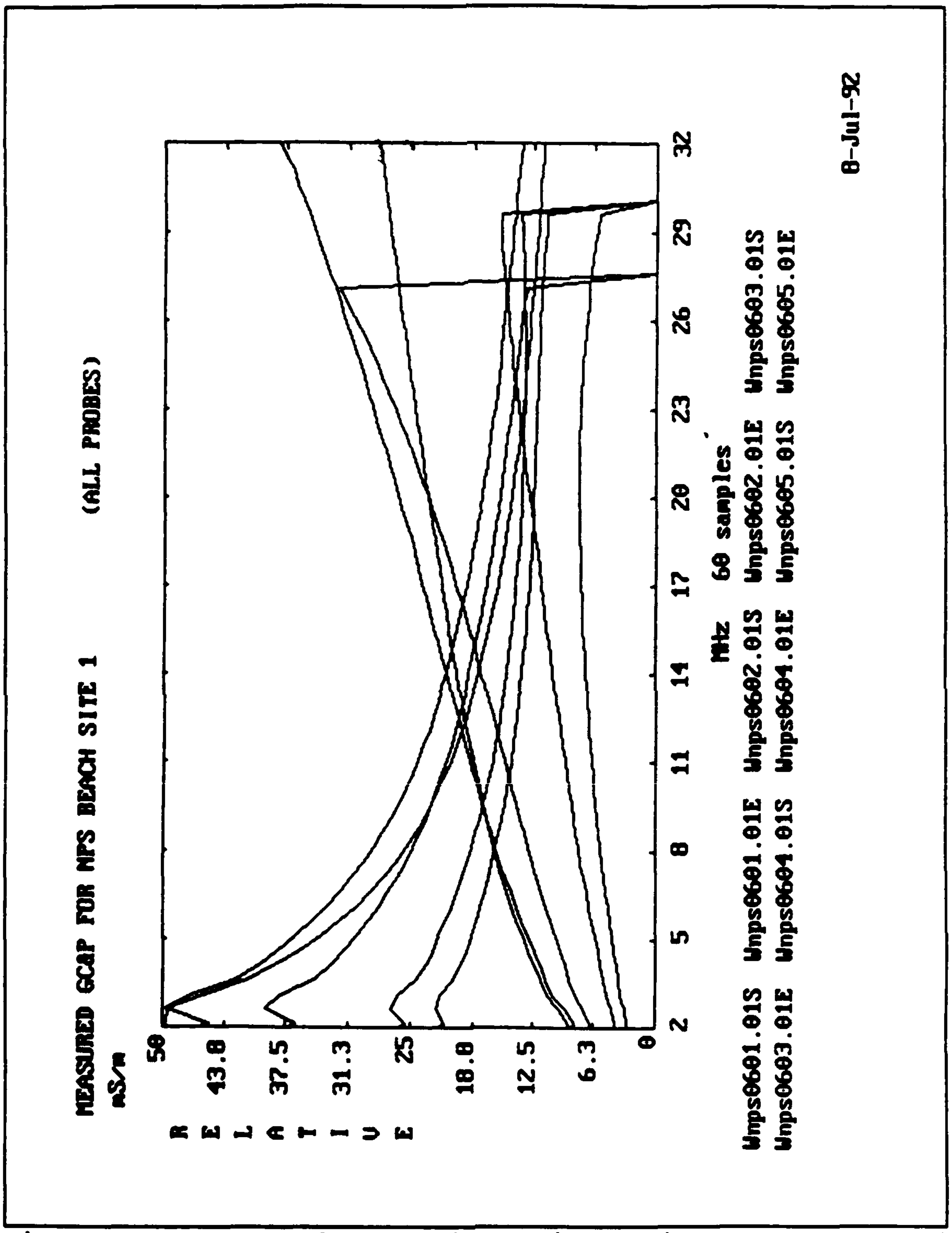

Figure 19. Measured Relative Dielectric Constant and Conductivity for NPS Beach Site 1.

B. SITE 2 GROUND MEASUREMENTS

6" Probe GNT , Cutoff Frequency = 117.54 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	34.1	6.51	1.63	5.75	142.93	20.27
3.10	29.3	7.65	1.51	4.46	96.82	15.08
4.10	26.3	8.38	1.40	3.79	73.21	12.24
5.10	23.9	9.18	1.35	3.28	58.85	10.39
6.10	22.0	9.86	1.32	2.91	49.20	9.10
7.10	20.4	10.44	1.30	2.64	42.27	8.15
8.10	19.2	11.03	1.28	2.42	37.06	7.39
9.10	18.2	11.55	1.25	2.24	32.98	6.78
10.10	17.4	12.05	1.23	2.09	29.72	6.26
11.09	16.7	12.46	1.21	1.97	27.04	5.84
12.09	16.1	12.89	1.19	1.87	24.81	5.47
13.09	15.7	13.33	1.17	1.78	22.91	5.14
14.09	15.2	13.73	1.15	1.70	21.29	4.86
15.09	14.9	14.12	1.13	1.63	19.88	4.60
16.09	14.5	14.51	1.12	1.56	18.64	4.38
17.09	14.2	14.85	1.10	1.50	17.55	4.18
18.09	13.8	15.23	1.10	1.44	16.58	4.01
19.09	13.5	15.58	1.09	1.39	15.71	3.84
20.09	13.2	15.94	1.08	1.35	14.93	3.70
21.09	12.9	16.30	1.08	1.30	14.23	3.56
22.09	12.6	16.63	1.07	1.26	13.58	3.44
23.09	12.3	17.01	1.08	1.22	12.99	3.33
24.09	12.1	17.37	1.07	1.18	12.45	3.22
25.09	11.9	17.74	1.07	1.15	11.96	3.12
26.09	11.7	18.09	1.07	1.11	11.50	3.03
27.09	11.5	18.44	1.06	1.08	11.08	2.94
28.09	11.4	18.83	1.06	1.06	10.68	2.86
29.09	11.2	19.18	1.06	1.03	10.31	2.78
30.09	11.1	19.53	1.05	1.00	9.97	2.70
31.08	11.0	19.90	1.05	1.98	9,65	2.63
32.08	10.9	20.29	1.04	1.96	9.35	2.56

12" Probe GNT , Cutoff Frequency = 51.57 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	34.5	6.70	1.66	5.65	142.93	20.07
3.10	30.0	8.06	1.56	4.31	96.82	14.80
4.10	27.0	8.73	1.42	3.70	73.21	12.05
5.10	24.6	9.66	1.38	3.17	58.85	10.20
6.10	22.5	10.47	1.37	2.80	49.20	8.93
7.10	20.7	11.18	1.37	2.51	42.27	8.00
8.10	19.4	11.83	1.35	2.29	37.06	7.26
9.10	18.3	12.47	1.35	2.11	32.98	6.66
10.10	17.4	13.08	1.34	1.96	29.72	6.16

11.09	16.6	13.62	1.33	1.83	27.04	5.75
12.09	15.9	14.12	1.32	1.73	24.81	5.40
13.09	15.4	14.62	1.30	1.64	22.91	5.08
14.09	14.8	15.12	1.30	1.55	21.29	4.81
15.09	14.4	15.55	1.29	1.49	19.88	4.57
16.09	14.0	16.02	1.28	1.42	18.64	4.35
17.09	13.6	16.47	1.27	1.36	17.55	4.16
18.09	13.2	16.89	1.27	1.31	16.58	3.99
19.09	12.9	17.34	1.27	1.26	15.71	3.83
20.09	12.5	17.79	1.27	1.21	14.93	3.69
21.09	12.2	18.27	1.28	1.16	14.23	3.56
22.09	11.9	18.72	1.28	1.12	13.58	3.44
23.09	11.6	19.20	1.29	1.08	12.99	3.33
24.09	11.4	19.69	1.29	1.04	12.45	3.22
25.09	11.1	20.25	1.31	1.01	11.96	3.12
26.09	11.0	20.81	1.30	1.97	11.50	3.02
27.09	10.8	21.35	1.31	0.94	11.08	2.93
28.09	10.7	21.90	1.31	0.91	10.68	2.84
29.09	10.5	22.48	1.32	0.88	10.31	2.76
30.09	10.4	23.02	1.32	0.86	9.97	2.68
31.08	10.2	23.58	1.34	0.83	9.65	2.62
32.08	10.1	24.17	1.34	0.81	9.35	2.55

18" Probe GNT , Cutoff Frequency = 31.08 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	35.0	5.54	1.36	6.57	142.93	20.85
3.10	31.8	6.85	1.25	4.99	96.93	15.06
4.10	29.1	7.51	1.13	4.28	73.21	12.11
5.10	27.1	8.47	1.10	3.64	58.85	10.14
6.10	25.2	9.42	1.10	3.16	49.20	8.79
7.10	23.4	10.23	1.11	2.80	42.27	7.83
8.10	22.1	11.02	1.11	2.53	37.06	7.06
9.10	21.0	11.78	1.11	2.31	32.98	6.45
10.10	20.0	12.55	1.12	2.12	29.72	5.94
11.09	19.1	13.25	1.12	1.96	27.04	5.53
12.09	18.3	13.89	1.13	1.83	24.81	5.18
13.09	17.7	14.52	1.13	1.72	22.91	4.87
14.09	17.1	15.17	1.13	1.62	21.29	4.60
15.09	16.5	15.77	1.14	1.53	19.88	4.36
16.09	16.0	16.43	1.15	1.45	18.64	4.15
17.09	15.6	17.03	1.15	1.38	17.55	3.96
18.09	15.1	17.68	1.16	1.31	16.58	3.79
19.09	14.8	18.32	1.17	1.26	15.71	3.63
20.09	14.4	19.05	1.18	1.19	14.93	3.49
21.09	14.0	19.77	1.20	1.14	14.23	3.36
22.09	13.7	20.49	1.22	1.09	13.58	3.23
23.09	13.4	21.33	1.24	1.04	12.99	3.12
24.09	13.2	22.16	1.25	0.99	12.45	3.00
25.09	13.0	23.07	1.27	0.95	11.96	2.90

26.09	12.8	24.06	1.30	0.91	11.50	2.80
27.09	12.6	25.05	1.32	0.87	11.08	2.71
28.09	12.5	26.14	1.34	0.83	10.68	2.61
29.09	12.4	27.24	1.36	0.80	10.31	2.53
30.09	12.2	28.46	1.39	0.76	9.97	2.45

24" Probe GNT , Cutoff Frequency = 22.59 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	27.9	4.65	1.43	7.07	142.93	23.11
3.10	25.4	5.81	1.33	5.32	96.82	16.65
4.10	23.3	6.50	1.22	4.48	73.21	13.35
5.10	21.8	7.43	1.20	3.78	58.85	11.13
6.10	20.2	8.33	1.22	3.25	49.20	9.65
7.10	18.7	9.15	1.24	2.86	42.27	8.59
8.10	17.7	9.95	1.25	2.56	37.06	7.73
9.10	16.8	10.77	1.27	2.31	32.98	7.04
10.10	15.9	11.58	1.30	2.10	29.72	6.49
11.09	15.2	12.35	1.32	1.93	27.04	6.02
12.09	14.5	13.09	1.34	1.79	24.81	5.63
13.09	14.0	13.85	1.36	1.66	22.91	5.28
14.09	13.6	14.65	1.37	1.55	21.29	4.97
15.09	13.1	15.43	1.40	1.45	19.88	4.71
16.09	12.8	16.25	1.42	1.37	18.64	4.46
17.09	12.4	17.09	1.45	1.29	17.55	4.24
18.09	12.1	18.01	1.48	1.21	16.58	4.04
19.09	11.8	18.98	1.51	1.14	15.71	3.86
20.09	11.5	20.05	1.56	1.07	14.93	3.69
21.09	11.2	21.17	1.61	1.01	14.23	3.53
22.09	10.9	22.48	1.68	0.95	13.58	3.39

31" Probe GNT , Cutoff Frequency = 18.59 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	27.3	4.56	1.43	7.13	142.93	23.35
3.10	25.1	5.57	1.29	5.48	96.82	16.85
4.10	22.9	6.07	1.16	4.71	73.21	13.59
5.10	21.7	6.85	1.11	4.04	58.85	11.31
6.10	20.4	7.67	1.11	3.49	49.20	9.76
7.10	19.1	8.45	1.12	3.07	42.27	8.65
8.10	18.1	9.21	1.13	2.75	37.06	7.78
9.10	17.3	10.05	1.15	2.47	32.98	7.06
10.10	16.4	10.90	1.18	2.23	29.72	6.50
11.09	15.6	11.74	1.22	2.03	27.04	6.03
12.09	14.8	12.56	1.26	1.86	24.81	5.64
13.09	14.2	13.38	1.29	1.72	22.91	5.30
14.09	13.6	14.28	1.34	1.59	21.29	4.99
15.09	12.9	15.19	1.40	1.47	19.88	4.74
16.09	12.2	16.14	1.48	1.36	18.64	4.52

17.09	11.5	17.16	1.57	1.26	17.55	4.33
18.09	10.7	18.24	1.69	1.16	16.58	4.16

Key:

MHZ =Frequency (Mhz)
Er =Effective Relative Permittivity
mS/m =Effective Conductivity (milli-Seimens/meter)
D.F =Dissipation Factor (Loss Tangent)
S.D =Skin Depth (meters)
W air =Wavelength in air (meters)
W gnd =Wavelength in ground (meters)

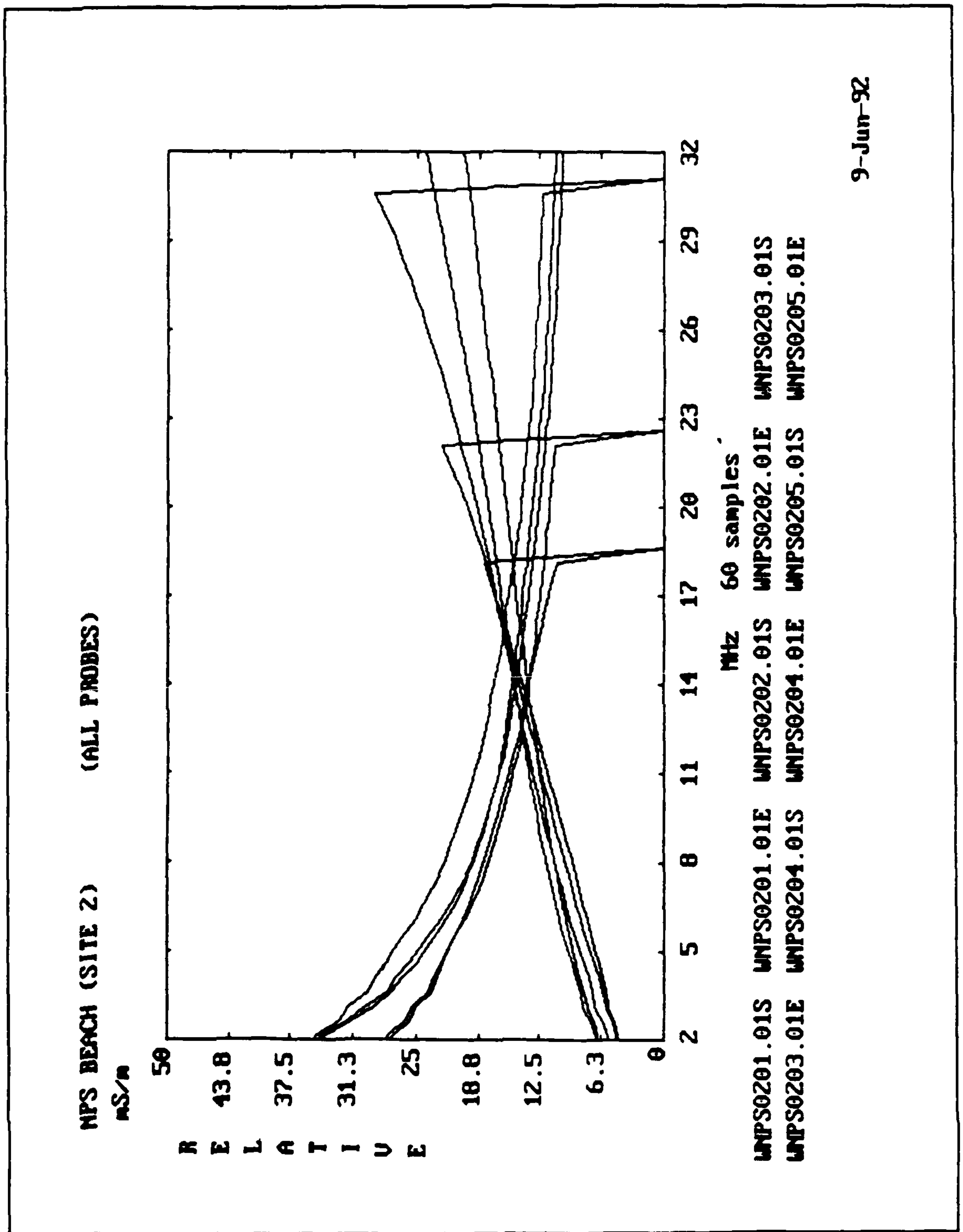

Figure 20. Measured Relative Dielectric Constant and Conductivity for NPS Beach Site 2.

C. SITE 3 GROUND MEASUREMENTS

6" Probe GNT , Cutoff Frequency = 174.01 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	29.5	8.42	2.44	4.62	142.93	19.50
3.10	37.9	10.65	1.63	3.71	96.82	13.03
4.10	31.5	11.65	1.62	3.09	73.21	10.82
5.10	28.7	12.83	1.57	2.66	58.85	9.17
6.10	25.9	13.90	1.58	2.33	49.20	8.07
7.10	23.5	14.85	1.60	2.08	42.27	7.26
8.10	21.6	15.64	1.61	1.90	37.06	6.63
9.10	20.0	16.40	1.62	1.74	32.98	6.12
10.10	18.5	17.02	1.64	1.62	29.72	5.72
11.09	17.4	17.58	1.64	1.52	27.04	5.37
12.09	16.4	18.16	1.64	1.43	24.81	5.06
13.09	15.6	18.66	1.64	1.36	22.91	4.80
14.09	14.9	19.55	1.64	1.29	21.29	4.57
15.09	14.3	19.61	1.64	1.24	19.88	4.36
16.09	13.7	20.07	1.64	1.18	18.64	4.17
17.09	13.2	20.53	1.64	1.13	17.55	4.00
18.09	12.7	21.00	1.64	1.09	16.58	3.85
19.09	12.3	21.43	1.64	1.05	15.71	3.71
20.09	11.9	21.84	1.64	1.01	14.93	3.58
21.09	11.6	22.27	1.64	0.98	14.23	3.46
22.09	11.2	22.70	1.65	0.95	13.58	3.35
23.09	10.9	23.11	1.65	0.92	12.99	3.25
24.09	10.6	23.52	1.65	0.89	12.45	3.16
25.09	10.4	23.90	1.65	0.87	11.96	3.07
26.09	10.1	24.32	1.66	0.84	11.50	2.99
27.09	9.9	24.71	1.66	0.82	11.08	2.91
28.09	9.6	25.09	1.67	0.80	10.68	2.84
29.09	9.4	25.45	1.68	0.78	10.31	2.77
30.09	9.2	25.83	1.69	0.76	9.97	2.71
31.08	8.9	26.20	1.69	0.74	9.65	2.65
32.08	8.7	26.55	1.70	0.72	9.35	2.59

12" Probe GNT , Cutoff Frequency = 34.58 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	34.2	7.26	1.82	5.31	142.93	19.71
3.10	46.2	9.62	1.21	4.25	96.82	12.57
4.10	39.3	10.84	1.21	3.48	73.21	10.30
5.10	36.6	12.36	1.19	2.94	58.85	8.60
6.10	33.6	13.85	1.21	2.52	49.20	7.48
7.10	30.8	15.22	1.25	2.21	42.27	6.68
8.10	28.4	16.42	1.28	1.98	37.06	6.07
9.10	26.3	17.63	1.32	1.78	32.98	5.57
10.10	24.4	18.69	1.36	1.63	29.72	5.18

11.09	22.9	19.66	1.39	1.51	27.04	4.85
12.09	21.5	20.66	1.43	1.40	24.81	4.57
13.09	20.4	21.60	1.46	1.31	22.91	4.32
14.09	19.3	22.53	1.49	1.22	21.29	4.10
15.09	18.3	23.48	1.52	1.15	19.88	3.91
16.09	17.5	24.38	1.56	1.09	18.64	3.73
17.09	16.7	25.31	1.60	1.03	17.55	3.58
18.09	15.9	26.23	1.64	0.98	16.58	3.44
19.09	15.3	27.21	1.68	0.93	15.71	3.31
20.09	14.6	28.06	1.72	0.88	14.93	3.20
21.09	14.0	29.07	1.77	0.84	14.23	3.09
22.09	13.4	29.99	1.83	0.80	13.58	2.99
23.09	12.8	30.90	1.88	0.77	12.99	2.90
24.09	12.2	31.81	1.94	0.74	12.45	2.82
25.09	11.7	32.76	2.01	0.71	11.96	2.75
26.09	11.2	33.78	2.08	0.68	11.50	2.67
27.09	10.6	34.70	2.16	0.65	11.08	2.61
28.09	10.0	35.68	2.27	0.62	10.68	2.55
29.09	9.5	36.62	2.38	0.60	10.31	2.50
30.09	8.9	37.60	2.51	0.57	9.97	2.45
31.08	8.4	38.43	2.65	0.55	9.65	2.41
32.08	7.9	39.48	2.82	0.53	9.35	2.36

18" Probe GNT , Cutoff Frequency = 30.58 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	25.9	4.86	1.61	6.69	142.93	23.35
3.10	33.9	6.15	1.05	5.57	96.82	15.02
4.10	29.9	6.95	1.02	4.61	73.21	12.14
5.10	28.6	7.89	0.97	3.94	58.85	10.05
6.10	27.0	8.89	0.98	3.40	49.20	8.66
7.10	25.4	9.84	0.98	2.98	42.27	7.66
8.10	24.0	10.70	0.99	2.67	37.06	6.90
9.10	22.7	11.61	1.01	2.40	32.98	6.29
10.10	21.4	12.42	1.03	2.19	29.72	5.81
11.09	20.4	13.16	1.04	2.02	27.04	5.41
12.09	19.6	13.92	1.06	1.87	24.81	5.06
13.09	18.8	14.66	1.07	1.74	22.91	4.76
14.09	18.1	15.39	1.08	1.63	21.29	4.50
15.09	17.5	16.14	1.10	1.53	19.88	4.26
16.09	17.0	16.87	1.11	1.45	18.64	4.05
17.09	16.4	17.66	1.13	1.37	17.55	3.87
18.09	16.0	18.41	1.14	1.30	16.58	3.69
19.09	15.6	19.21	1.16	1.23	15.71	3.54
20.09	15.2	20.02	1.18	1.17	14.93	3.40
21.09	14.8	20.83	1.20	1.11	14.23	3.26
22.09	14.6	21.70	1.21	1.06	13.58	3.14
23.09	14.3	22.57	1.23	1.01	12.99	3.02
24.09	14.0	23.50	1.25	0.96	12.45	2.92
25.09	13.8	24.43	1.27	0.92	11.96	2.82

26.09	13.5	25.43	1.30	0.88	11.50	2.72
27.09	13.3	26.52	1.33	0.84	11.08	2.64
28.09	13.0	27.74	1.36	0.80	10.68	2.55
29.09	12.9	29.00	1.39	0.77	10.31	2.47
30.09	12.6	30.51	1.45	0.73	9.97	2.39

24" Probe GNT , Cutoff Frequency = 27.09 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	18.8	3.87	1.76	7.33	142.93	26.78
3.10	25.7	4.76	1.07	6.29	96.82	17.19
4.10	22.7	5.34	1.03	5.23	73.21	13.92
5.10	21.9	6.00	0.96	4.53	58.85	11.50
6.10	20.9	6.73	0.95	3.93	49.20	9.87
7.10	19.8	7.44	0.95	3.47	42.27	8.71
8.10	18.8	8.11	0.96	3.10	37.06	7.83
9.10	17.9	8.81	0.97	2.79	32.98	7.12
10.10	17.0	9.45	0.99	2.54	29.72	6.57
11.09	16.2	10.01	1.00	2.35	27.04	6.12
12.09	15.6	10.60	1.01	2.18	24.81	5.71
13.09	15.0	11.18	1.02	2.03	22.91	5.37
14.09	14.5	11.75	1.04	1.90	21.29	5.07
15.09	14.0	12.32	1.05	1.79	19.88	4.80
16.09	13.6	12.88	1.06	1.69	18.64	4.56
17.09	13.2	13.48	1.07	1.59	17.55	4.35
18.09	12.9	14.06	1.08	1.51	16.58	4.15
19.09	12.6	14.64	1.09	1.43	15.71	3.97
20.09	12.3	15.27	1.11	1.36	14.93	3.81
21.09	12.1	15.91	1.12	1.30	14.23	3.66
22.09	11.9	16.60	1.14	1.24	13.58	3.51
23.09	11.7	17.31	1.15	1.18	12.99	3.38
24.09	11.5	18.09	1.17	1.12	12.45	3.26
25.09	11.3	18.88	1.20	1.07	11.96	3.14
26.09	11.2	19.78	1.22	1.02	11.50	3.03

31" Probe GNT , Cutoff Frequency = 24.59 Mhz.

Mhz	Er	mS/m	D.F	S.D	W air	W grd
2.10	18.1	2.77	1.31	9.39	142.93	29.20
3.10	23.5	3.28	0.81	8.39	96.82	18.69
4.10	21.3	3.78	0.78	6.90	73.21	14.91
5.10	20.7	4.31	0.73	5.94	58.85	12.21
6.10	19.9	4.89	0.72	5.13	49.20	10.43
7.10	19.1	5.49	0.73	4.47	42.27	9.15
8.10	18.3	6.02	0.73	4.00	37.06	8.18
9.10	17.6	6.60	0.74	3.58	32.98	7.41
10.10	16.9	7.11	0.75	3.26	29.72	6.82
11.09	16.3	7.58	0.75	3.00	27.04	6.31
12.09	15.8	8.07	0.76	2.78	24.81	5.87

13.09	15.4	8.52	0.76	2.60	22.91	5.50
14.09	15.0	8.98	0.76	2.43	21.99	5.17
15.09	14.7	9.43	0.76	2.29	19.88	4.88
16.09	14.4	9.87	0.76	2.17	18.64	4.62
17.09	14.2	10.33	0.77	2.06	17.55	4.38
18.09	14.0	10.75	0.76	1.96	16.58	4.17
19.09	13.9	11.20	0.76	1.88	15.71	3.97
20.09	13.8	11.65	0.75	1.80	14.93	3.78
21.09	13.7	12.05	0.75	1.73	14.23	3.62
22.09	13.8	12.51	0.74	1.67	13.58	3.45
23.09	13.9	12.87	0.72	1.62	12.99	3.30
24.09	14.0	13.20	0.70	1.59	12.45	3.15

Key:

MHZ =Frequency (Mhz)
Er =Effective Relative Permittivity
mS/m =Effective Conductivity (milli-Seimens/meter)
D.F =Dissipation Factor (Loss Tangent)
S.D =Skin Depth (meters)
W air =Wavelength in air (meters)
W gnd =Wavelength in ground (meters)

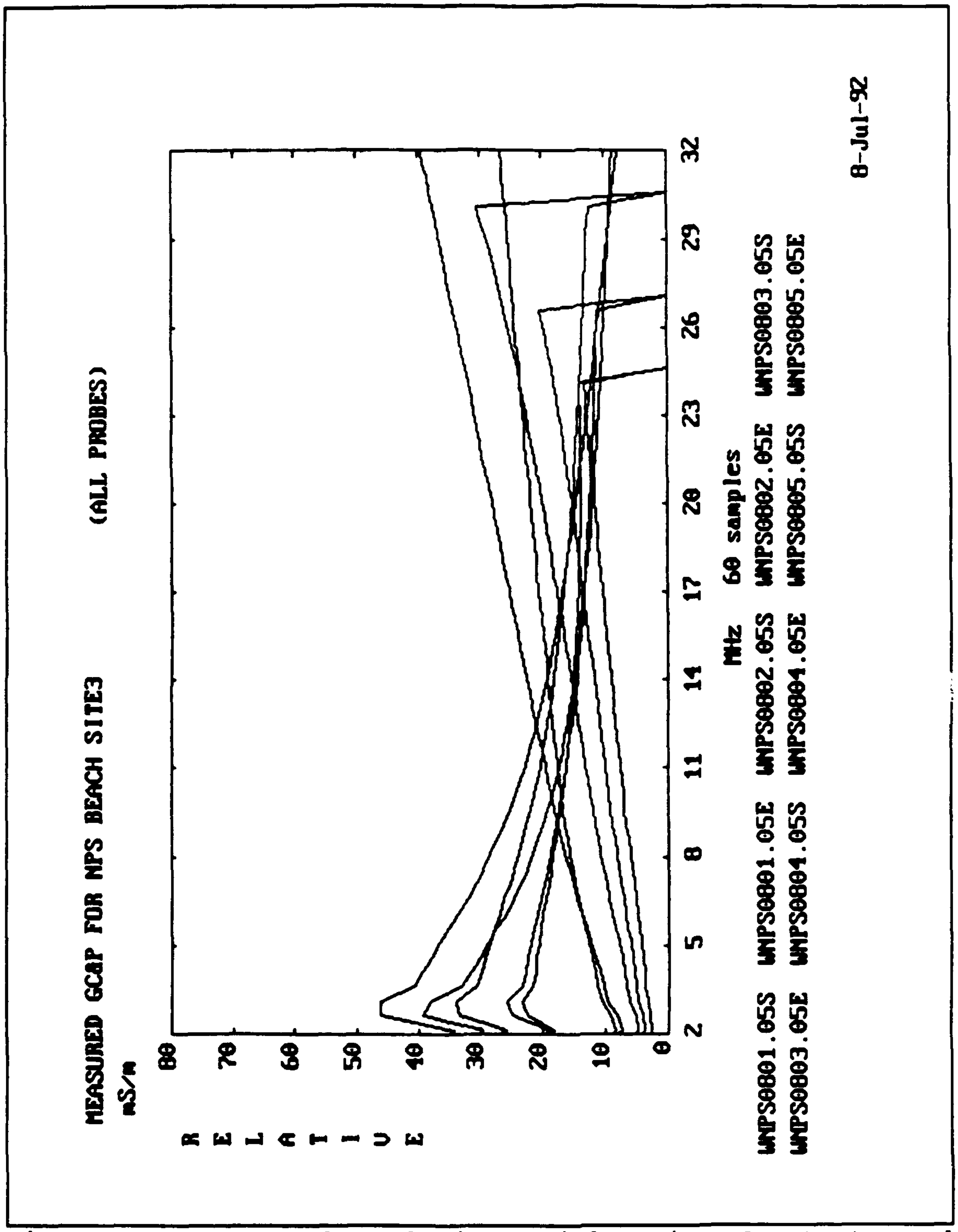

Figure 21. Measured Relative Dielectric Constant and Conductivity for NPS Beach Site 3.

APPENDIX B. NEC DATA SETS

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CM SLOPING " VEE BEAM " DIPOLE.
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 5.60 Mhz
CM GROUND: EPSILON = 25.5 , SIGMA = 0.009 , " NPS BEACH "
CE
GW1,40,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,40,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,5.60,0.,
GN2,0,0,0,25.5,0.009,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
RP0,1,361,1000,85.,0.,0.,1.,0.,0.,
RP0,1,361,1000,80.,0.,0.,1.,0.,0.,
RP0,1,361,1000,75.,0.,0.,1.,0.,0.,
RP0,1,361,1000,70.,0.,0.,1.,0.,0.,
RP0,1,361,1000,65.,0.,0.,1.,0.,0.,
RP0,1,361,1000,60.,0.,0.,1.,0.,0.,
RP0,1,361,1000,55.,0.,0.,1.,0.,0.,
RP0,1,361,1000,50.,0.,0.,1.,0.,0.,
RP0,1,361,1000,45.,0.,0.,1.,0.,0.,
RP0,1,361,1000,40.,0.,0.,1.,0.,0.,
RP0,1,361,1000,30.,0.,0.,1.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE.
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
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CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 11 Mhz
CM GROUND: EPSILON = 18.3 , SIGMA = 0.013 , " NPS BEACH "
CE
GW1,76,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,76,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,11.0,0.,
GN2,0,0,0,18.3,0.013,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
RP0,1,361,1000,85.,0.,0.,1.,0.,0.,
RP0,1,361,1000,80.,0.,0.,1.,0.,0.,
RP0,1,361,1000,75.,0.,0.,1.,0.,0.,
RP0,1,361,1000,70.,0.,0.,1.,0.,0.,
RO0,1,361,1000,65.,0.,0.,1.,0.,0.,
RP0,1,361,1000,60.,0.,0.,1.,0.,0.,
RP0,1,361,1000,55.,0.,0.,1.,0.,0.,
RP0,1,361,1000,50.,0.,0.,1.,0.,0.,
RP0,1,361,1000,45.,0.,0.,1.,0.,0.,
EN

CM SLOPING " VEE BEAM " DIPOLE.
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 16.8 Mhz
CM GROUND: EPSILON = 14.6 , SIGMA = 0.016 , " NPS BEACH "
CE
GW1,116,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,116,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
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GC0,0,1.0046,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,16.8,0.,
GN2,0,0,0,14.65,0.01682,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
RP0,1,361,1000,85.,0.,0.,1.,0.,0.,
RP0,1,361,1000,80.,0.,0.,1.,0.,0.,
RP0,1,361,1000,75.,0.,0.,1.,0.,0.,
RP0,1,361,1000,70.,0.,0.,1.,0.,0.,
RP0,1,361,1000,65.,0.,0.,1.,0.,0.,
RP0,1,361,1000,60.,0.,0.,1.,0.,0.,
RP0,1,361,1000,55.,0.,0.,1.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE.
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 5.60 Mhz
CM EPSILON = 12 , SIGMA = 0.005 , " FAIR GROUND "
CE
GW1,40,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,40,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,5.60,0.,
GN2,0,0,0,12.0,0.005,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
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RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
FREQUENCY: 11 Mhz
CM EPSILON = 12 , SIGMA = 0.005 , " FAIR GROUND "
CE
GW1,76,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,76,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,11.0,0.,
GN2,0,0,0,12.0,0.005,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY   : 16.8 Mhz
CM EPSILON = 12 , SIGMA = 0.005 , " FAIR GROUND "
CE
GW1,116,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,116,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
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GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,16.8,0.,
GN2,0,0,0,12.0,0.005,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 5.60 Mhz
CM EPSILON = 10 , SIGMA = 0.003 , " AVERAGE GROUND "
CE
GW1,40,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,40,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,5.60,0.,
GN2,0,0,0,10.0,0.003,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
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CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM INTERIOR ANGLE = 60 DEGREES
CM FREQUENCY: 11 Mhz
CM EPSILON = 10 , SIGMA = 0.003 , " AVERAGE GROUND "
CE
GW1,76,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,76,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,11.0,0.,
GN2,0,0,0,10.0,0.003,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 16.8 Mhz
CM EPSILON = 10 , SIGMA = 0.003 , " AVERAGE GROUND "
CE
GW1,116,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,116,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,16.8,0.,
GN2,0,0,0,10.0,0.003,
```

```
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 5.60 Mhz
CM EPSILON = 5 , SIGMA = 0.001 , " POOR GROUND "
CE
GW1,40,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,40,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,5.60,0.,
GN2,0,0,0,5.0,0.001,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 11 Mhz
CM EPSILON = 5 , SIGMA = 0.002 , " POOR GROUND "
CE
GW1,76,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,76,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
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GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,11.0,0.,
GN2,0,0,0,5.0,0.001,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 16.8 Mhz
CM EPSILON = 5 , SIGMA = 0.001 , " POOR GROUND "
CE
GW1,116,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,116,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,16.8,0.,
GN2,0,0,0,5.0,0.001,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
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CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 5.60 Mhz
CM ARCTIC GROUND: EPSILON = 55 , SIGMA = 0.017 , " WET "
CE
GW1,40,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,40,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,5.60,0.,
GN2,0,0,0,55.0,0.017,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM GEOMETRY   : SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 11 Mhz
CM ARCTIC GROUND: EPSILON = 40 , SIGMA = 0.018 , " WET "
CE
GW1,76,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,76,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
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FR0,1,0,0,11.0,0.,
GN2,0,0,0,40.0,0.018,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM GEOMETRY   : SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 16.8 Mhz
CM ARCTIC GROUND: EPSILON = 33 , SIGMA = 0.021 , " WET "
CE
GW1,116,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,116,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,16.8,0.,
GN2,0,0,0,33.0,0.021,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN
CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 5.60 Mhz
CM ARCTIC GROUND: EPSILON = 20 , SIGMA = 0.005 , " DRY "
CE
GW1,40,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,40,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
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GC0,0,1.0208,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,5.60,0.,
GN2,0,0,0,20.0,0.005,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY 11 Mhz
CM ARCTIC GROUND: EPSILON = 16 , SIGMA = 0.006 , " DRY "
CE
GW1,76,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,76,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,11.0,0.,
GN2,0,0,0,16.0,0.006,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
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CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM INTERIOR ANGLE = 60 DEGREES
CM FREQUENCY: 16.8 Mhz
CM ARCTIC GROUND: EPSILON = 11 , SIGMA = 0.006 , " DRY "
CE
GW1,116,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,116,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,16.8,0.,
GN2,0,0,0,11.0,0.006,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
RP0,1,361,1000,75.,0.,0.,1.,0.,0.,
RP0,1,361,1000,70.,0.,0.,1.,0.,0.,
RP0,1,361,1000,65.,0.,0.,1.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 5.60 Mhz
CM ARCTIC GROUND: EPSILON = 12 , SIGMA = 0.001 , "FROZEN"
CE
GW1,40,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,40,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0208,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
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GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,5.60,0.,
GN2,0,0,0,12.0,0.001,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
CM FREQUENCY: 11 Mhz
CM ARCTIC GROUND: EPSILON = 8.7 , SIGMA = 0.002 , "FROZEN"
CE
GW1,76,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,76,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0090,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,11.0,0.,
GN2,0,0,0,8.7,0.002,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN

CM SLOPING " VEE BEAM " DIPOLE
CM APEX HEIGHT = 50 Ft , INTERIOR ANGLE = 60 DEGREES.
CM LENGTH OF EATH LEG OF "VEE" = 450 FEET.
CM EACH LEG OF "VEE" IS TERMINATED THROUGH A 450-Ohm RESISTOR.
CM HEIGHT OF LEGS OVER THE GROUND = 7 Ft.
CM DEPTH OF ENDS IN THE GROUND = 2 Ft.
```

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CM FREQUENCY: 16.8 Mhz
CM ARCTIC GROUND: EPSILON = 7 , SIGMA = 0.003 , "FROZEN"
CE
GW1,116,0.,0.,15.24,118.2405,68.2662,2.1336,0.002,
GW2,116,0.,0.,15.24,118.2405,-68.2662,2.1336,0.002,
GW3,4,118.2405,68.2662,0.,118.2405,68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW4,4,118.2405,-68.2662,0.,118.2405,-68.2662,2.1336,0.,
GC0,0,1.0046,0.002,0.002,
GW5,2,118.2405,68.2662,0.,118.2405,68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GW6,2,118.2405,-68.2662,0.,118.2405,-68.2662,-0.6096,0.,
GC0,0,1.0,0.002,0.002,
GE-1,0,0.,
LD4,3,4,4,450.,0.,
LD4,4,4,4,450.,0.,0,
FR0,1,0,0,16.8,0.,
GN2,0,0,0,7.0,0.003,
EX0,1,1,01,0.5,0.,0.,
EX0,2,1,01,-0.5,0.,0.,
RP0,91,7,1501,0.,0.,1.,15.,0.,0.,
RP0,181,1,1000,-90.,0.,1.,0.,0.,0.,
XQ0,
EN
```

APPENDIX C. SLOPING-VEE ANTENNA RADIATION PATTERNS

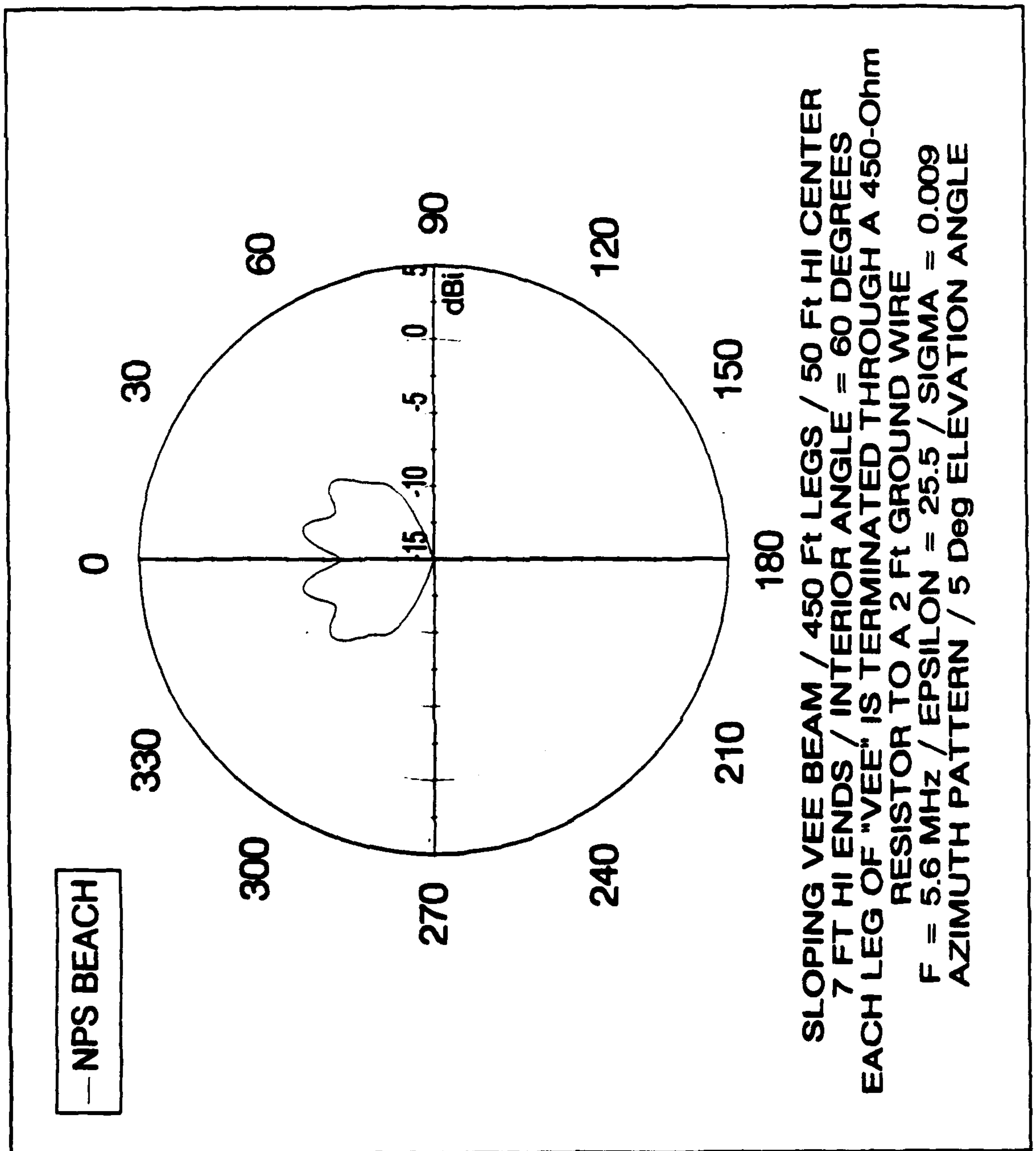

Figure 22. Sloping-Vee Beam Azimuth Radiation Pattern (θ=85°), over the NPS Beach Ground at 5.6 MHz.

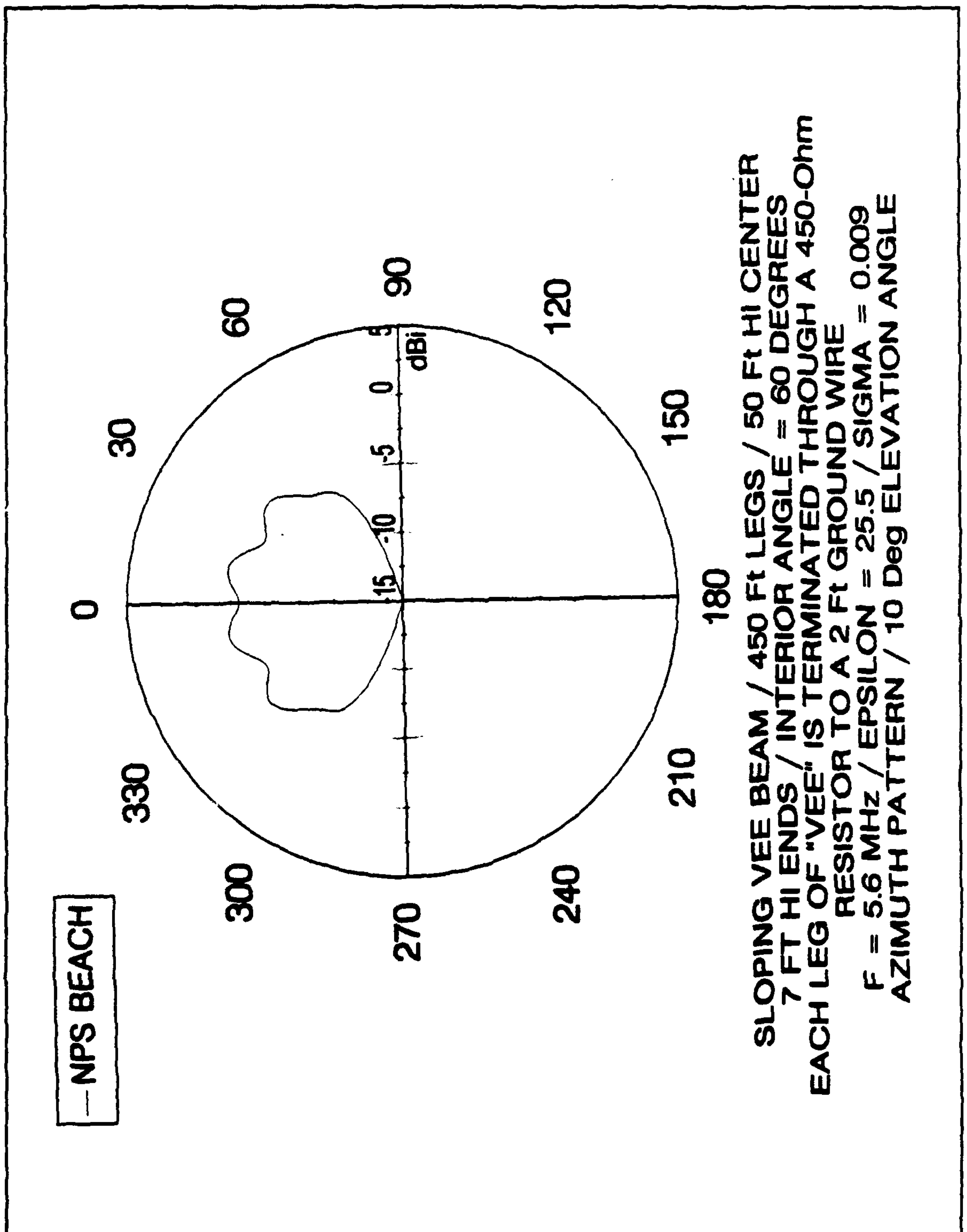

Figure 23. Sloping-Vee Beam Azimuth Radiation Pattern ($\theta=80^{\circ}$), over the NPS Beach Ground at 5.6 MHz.

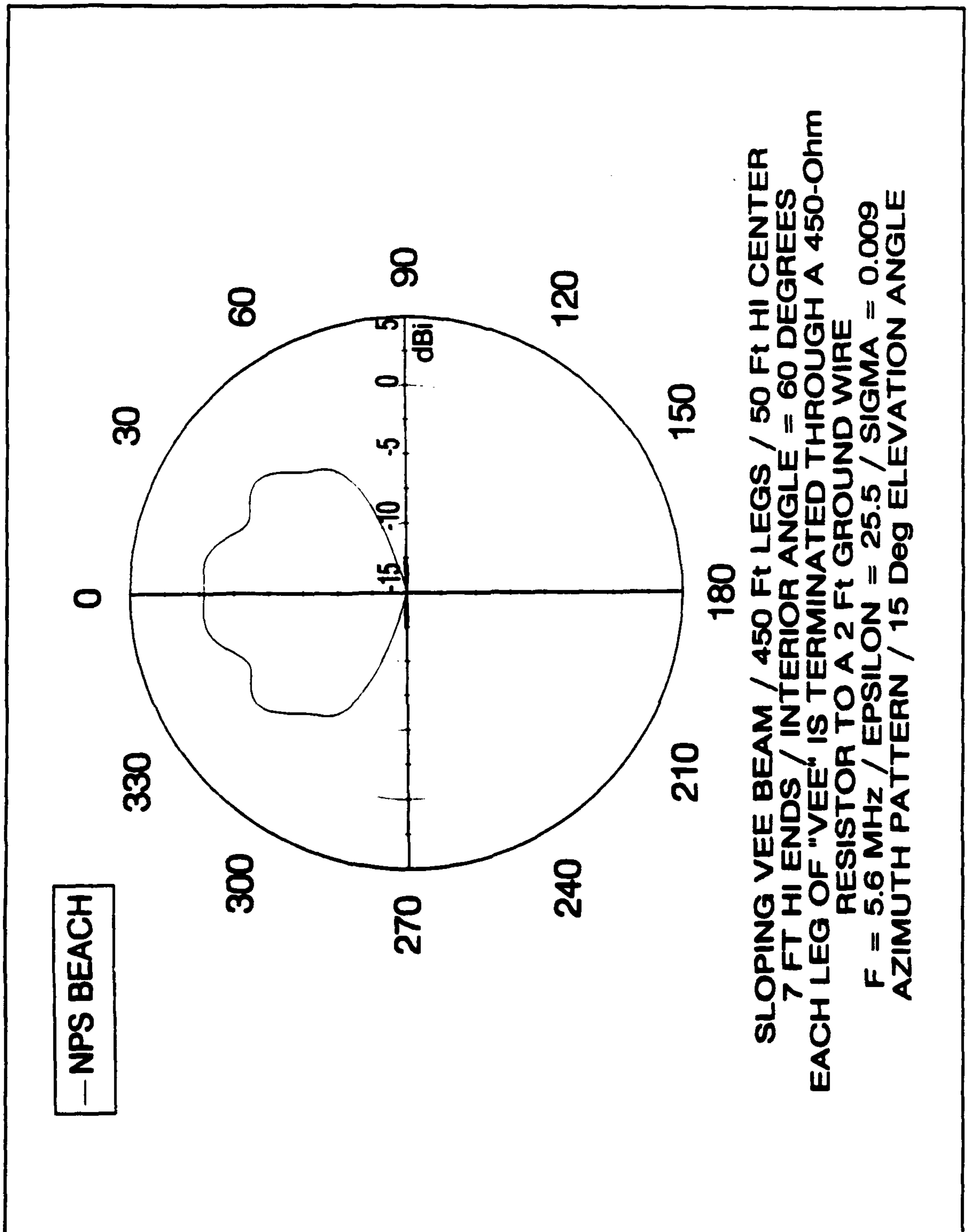

Figure 24. Sloping-Vee Beam Azimuth Radiation Pattern (θ=75°), over the NPS Beach Ground at 5.6 MHz.

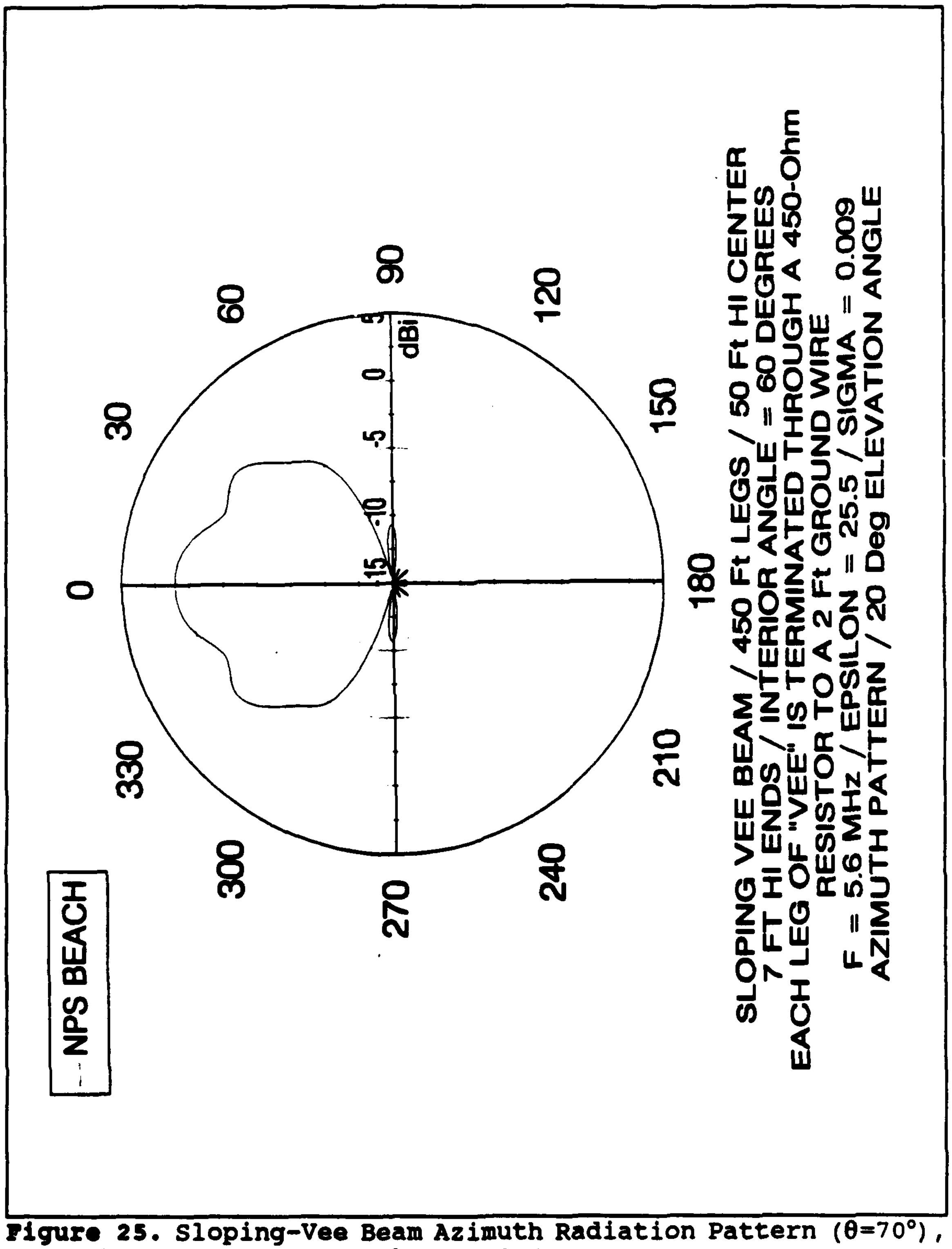

Figure 25. Sloping-Vee Beam Azimuth Radiation Pattern (θ=70°), over the NPS Beach Ground at 5.6 MHz.

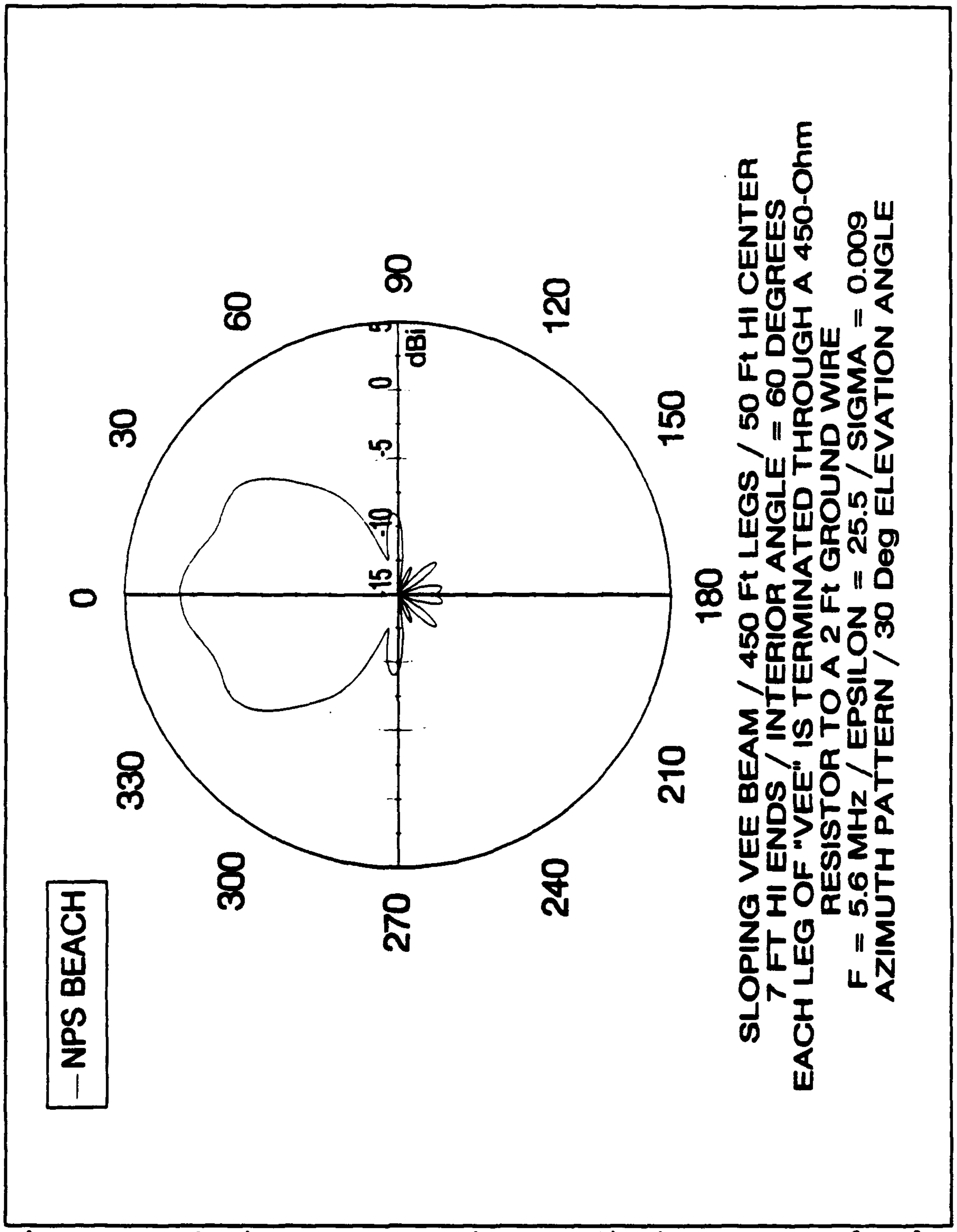

Figure 26. Sloping-Vee Beam Azimuth Radiation Pattern ($\theta=60^{\circ}$), over the NPS Beach Ground at 5.6 MHz.

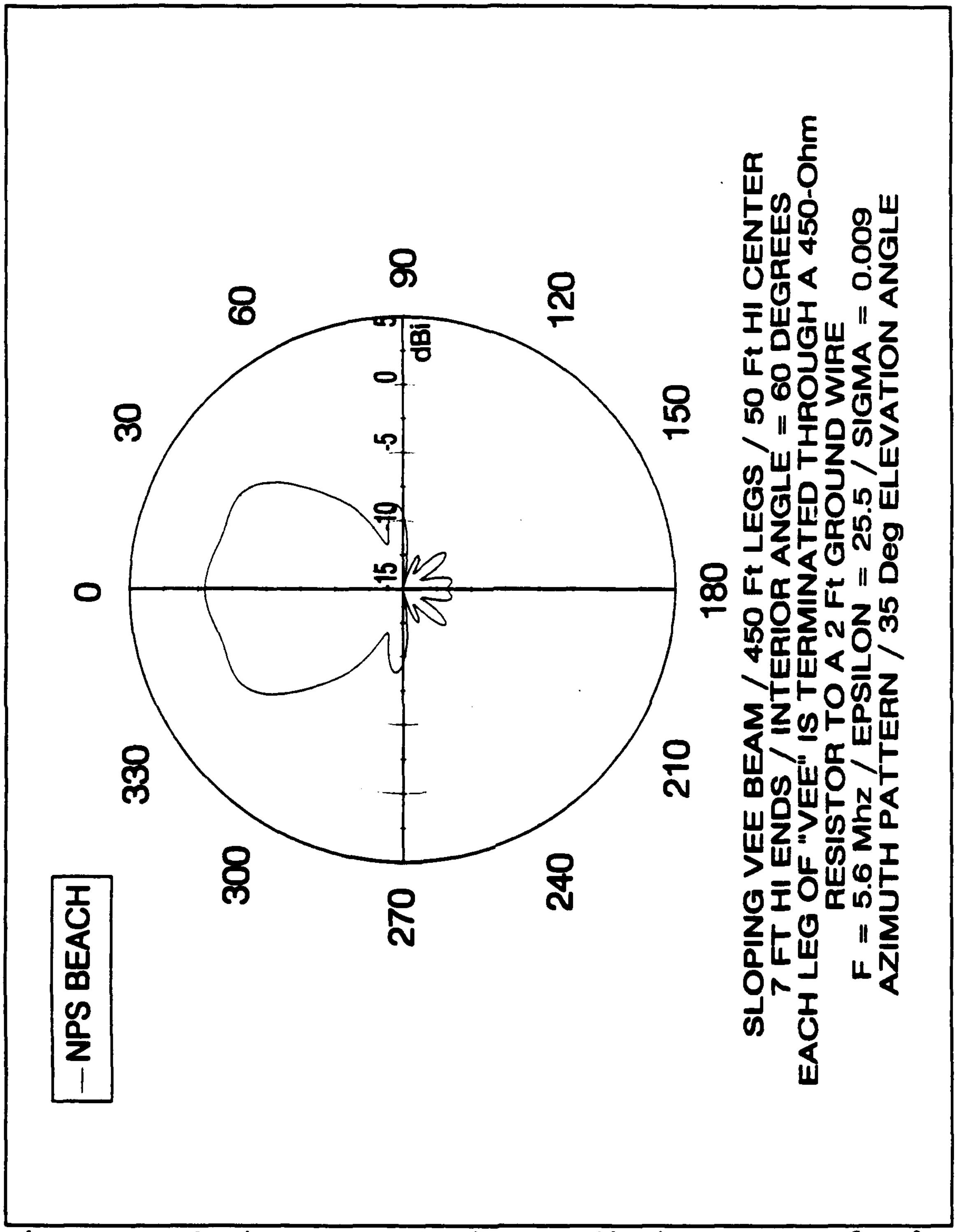

Figure 27. Sloping-Vee Beam Azimuth Radiation Pattern (θ=55°), over the NPS Beach Ground at 5.6 MHz.

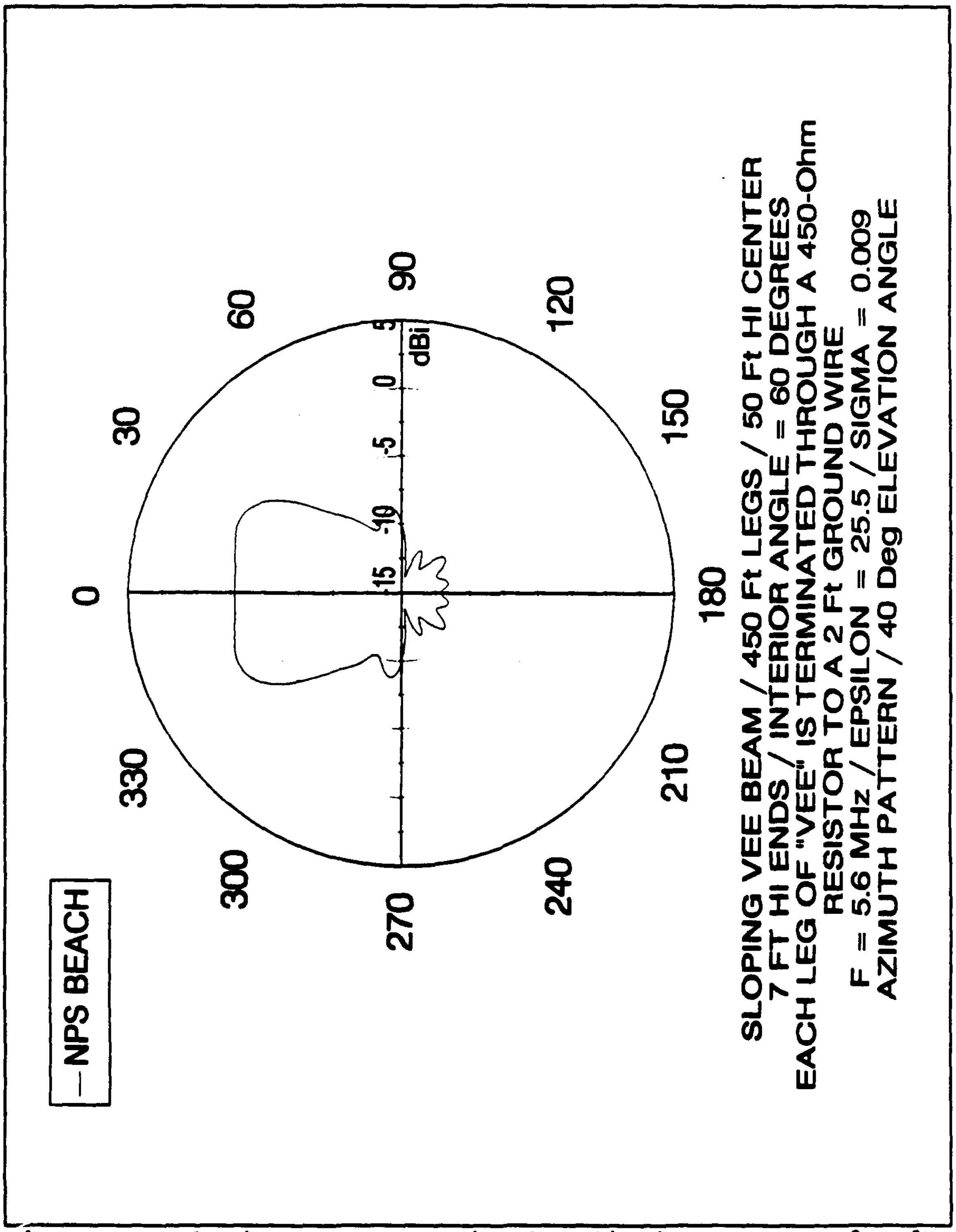

Figure 28. Sloping-Vee Beam Azimuth Radiation Pattern (θ=50°), over the NPS Beach Ground at 5.6 MHz.

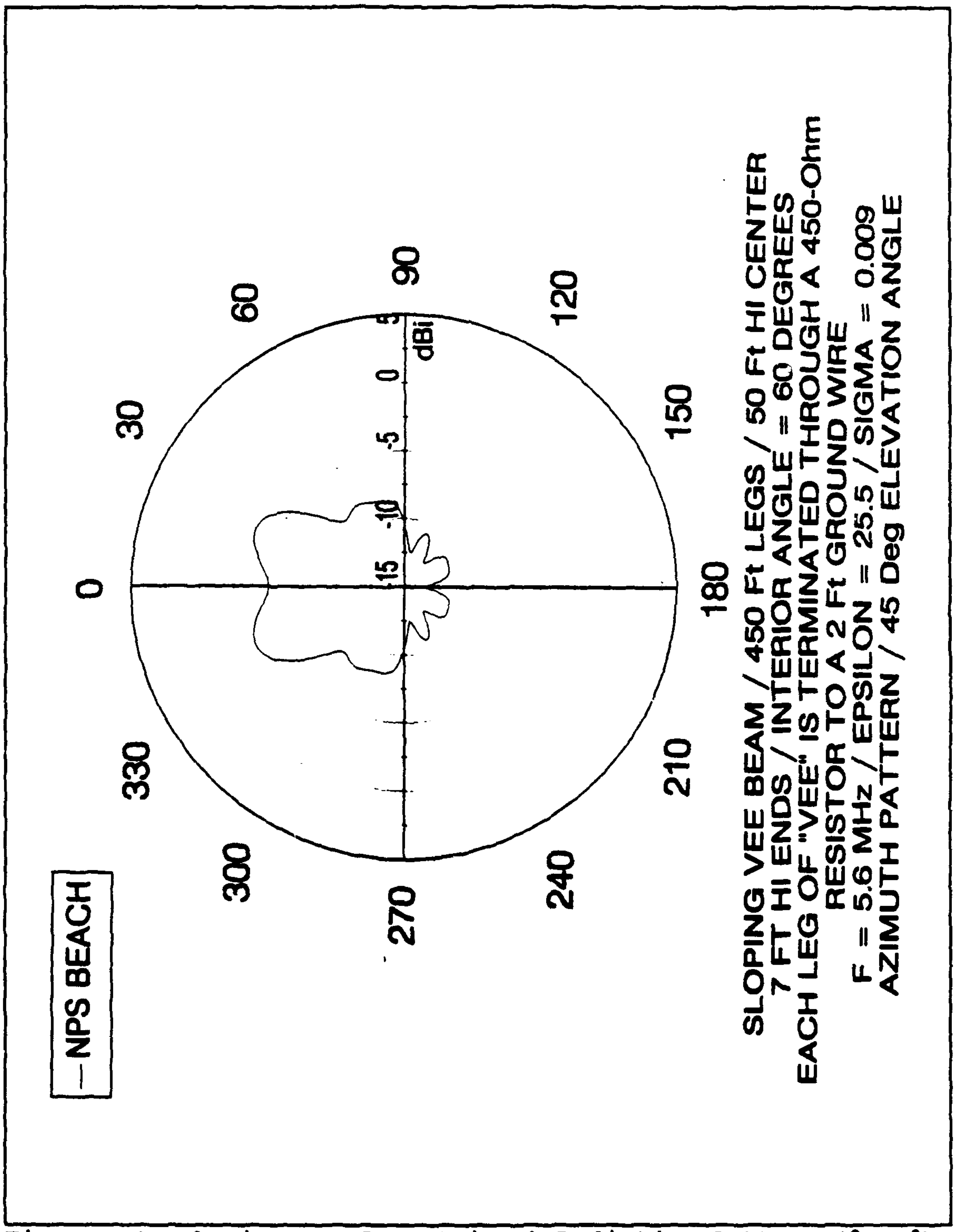

Figure 29. Sloping-Vee Beam Azimuth Radiation Pattern (θ=45°), over the NPS Beach Ground at 5.6 MHz.

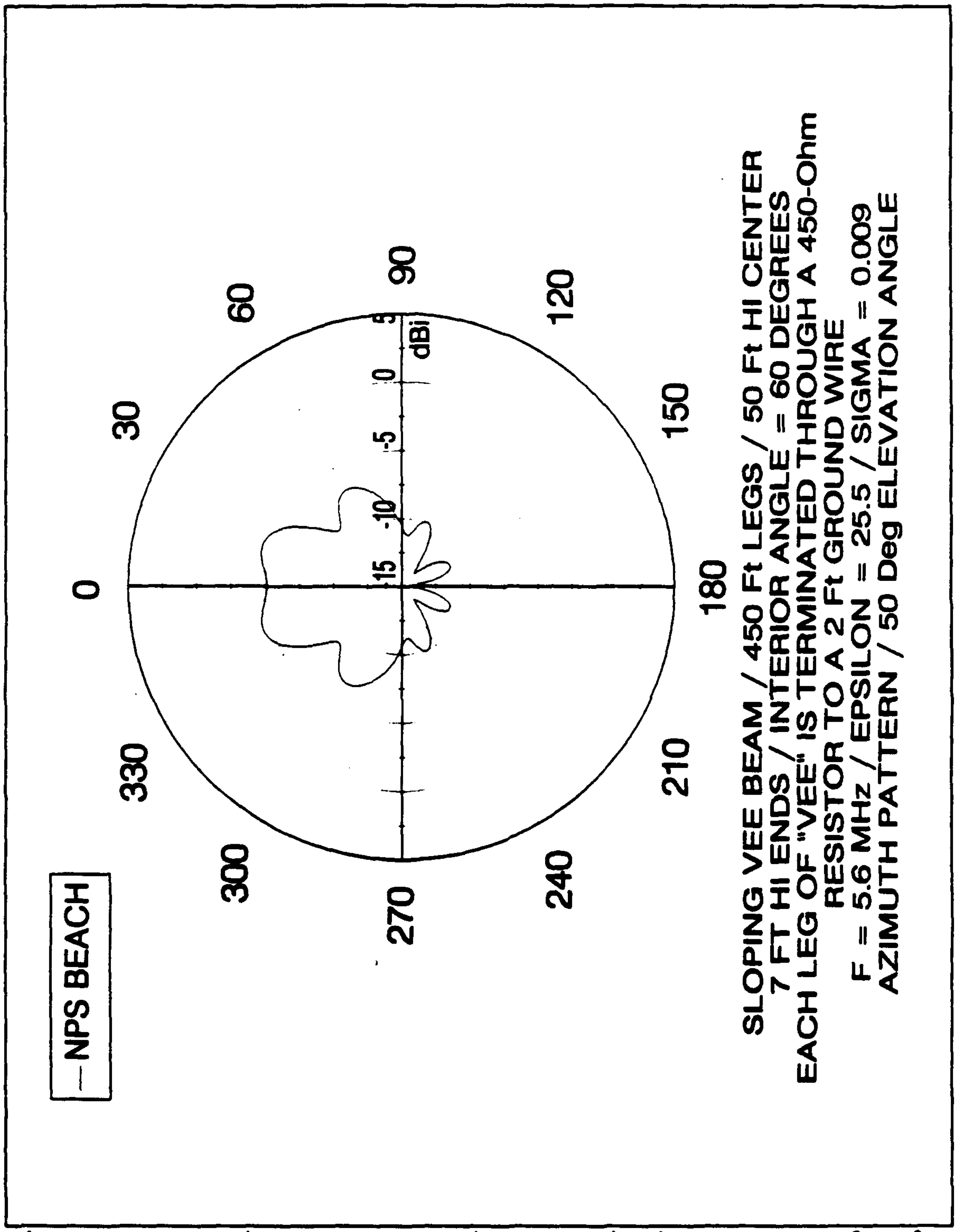

Figure 30. Sloping-Vee Beam Azimuth Radiation Pattern (θ=40°), over the NPS Beach Ground at 5.6 MHz.

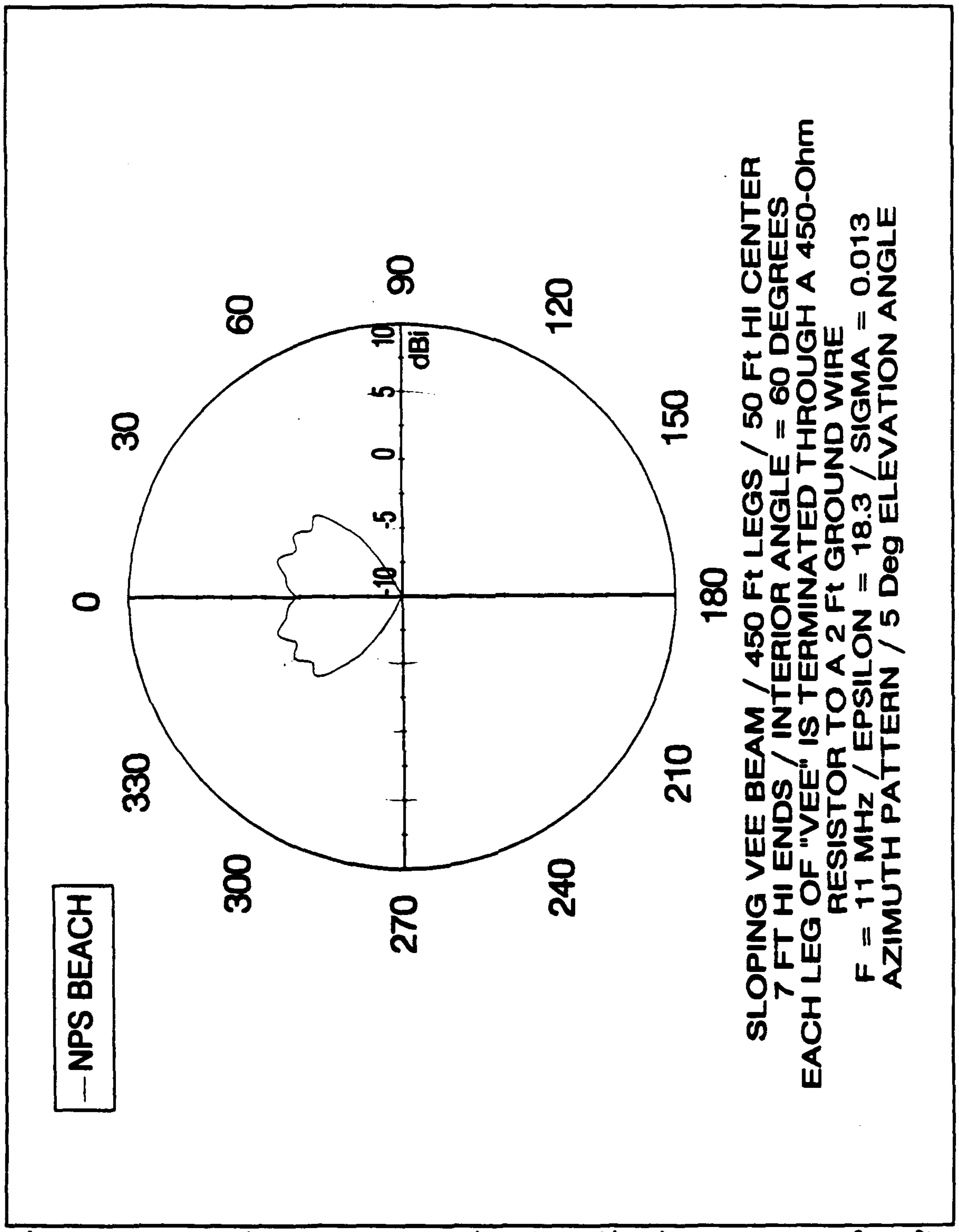

Figure 31. Sloping-Vee Beam Azimuth Radiation Pattern (θ=85°), over the NPS Beach Ground at 11 MHz.

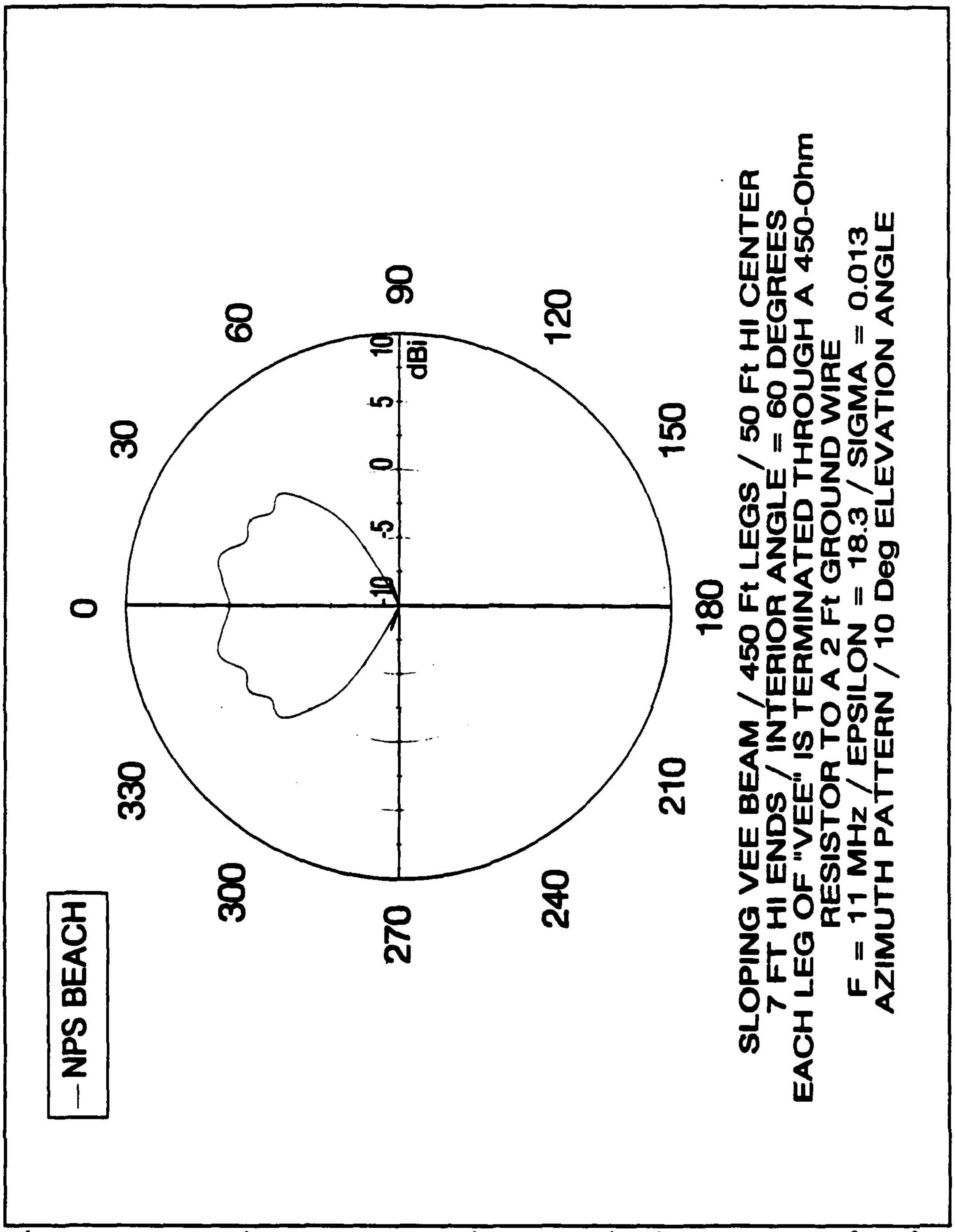

Figure 32. Sloping-Vee Beam Azimuth Radiation Pattern ($\theta=80°$), over the NPS Beach Ground at 11 MHz.

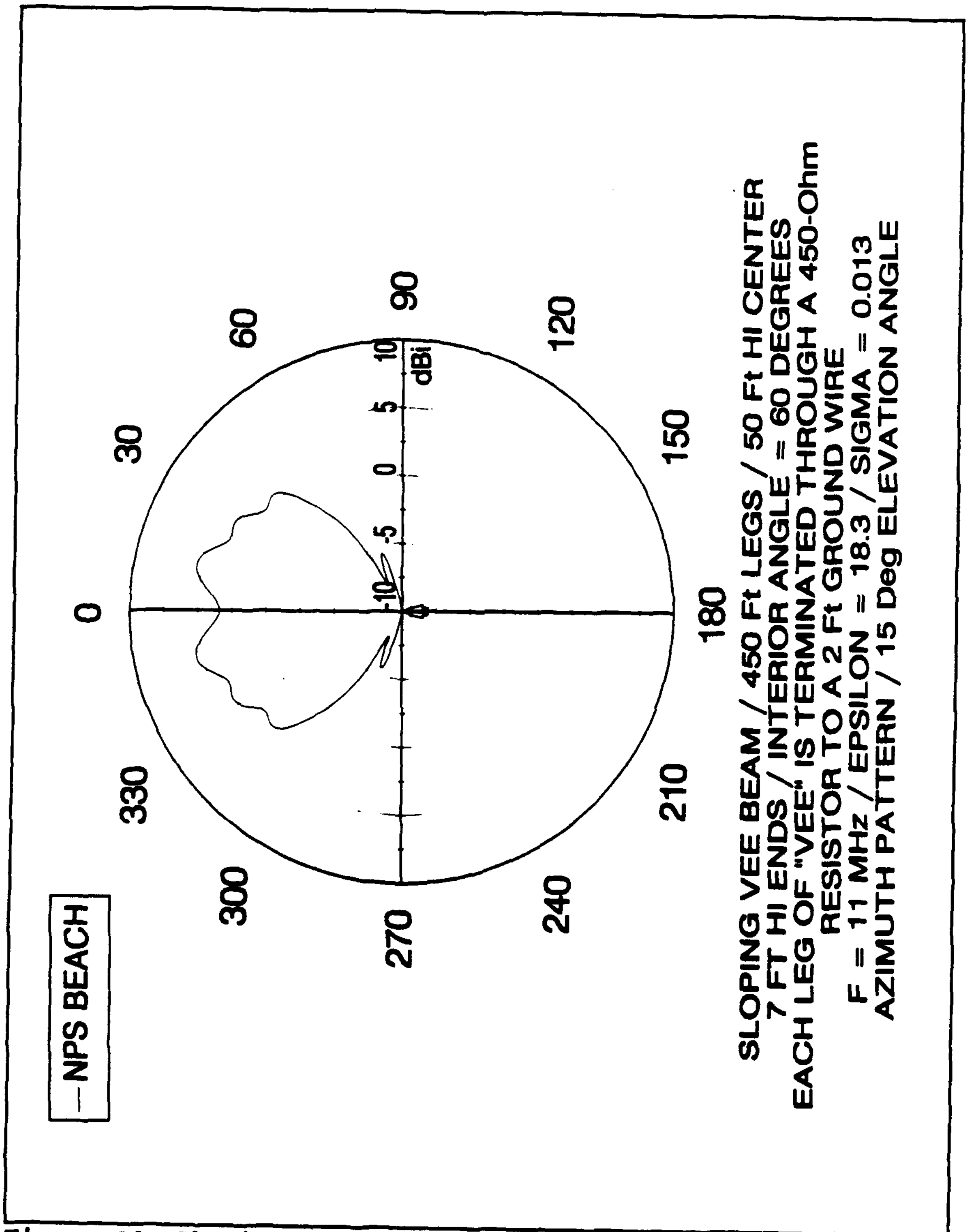

Figure 33. Sloping-Vee Beam Azimuth Radiation Pattern (θ=75°), over the NPS Beach Ground at 11 MHz.

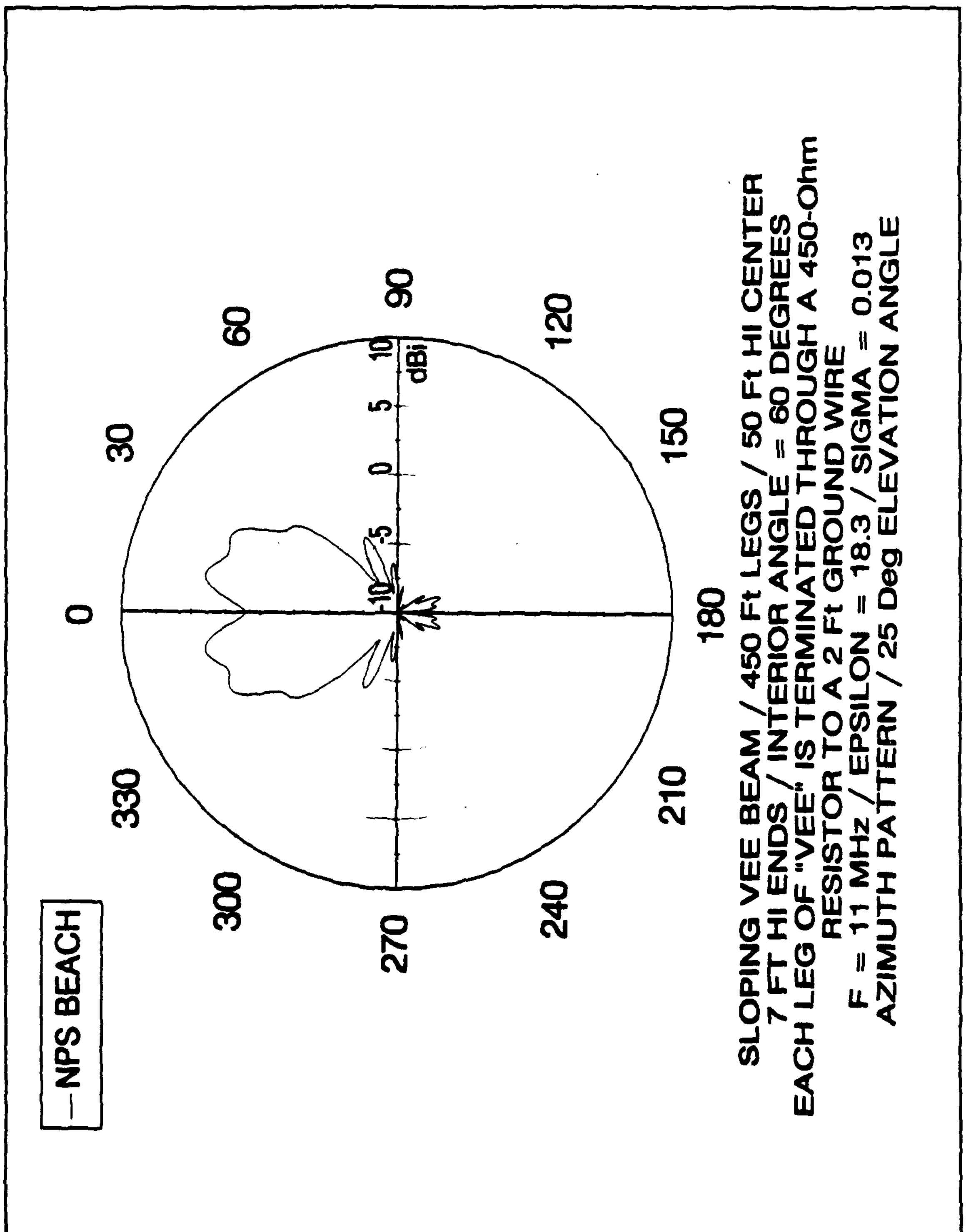

Figure 34. Sloping-Vee Beam Azimuth Radiation Pattern (θ=65°), over the NPS Beach Ground at 11 MHz.

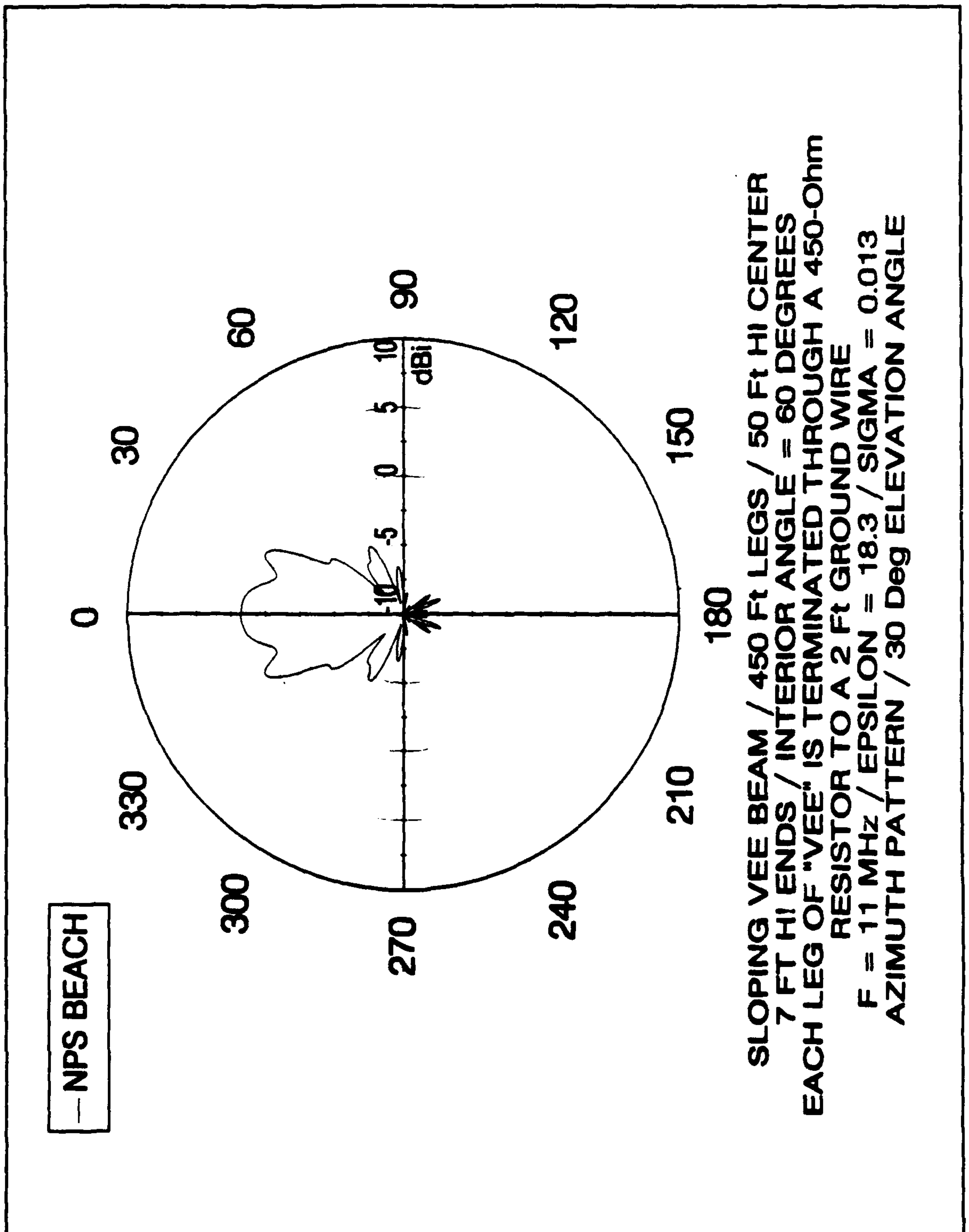

Figure 35. Sloping-Vee Beam Azimuth Radiation Pattern (θ=60°), over the NPS Beach Ground at 11 MHz.

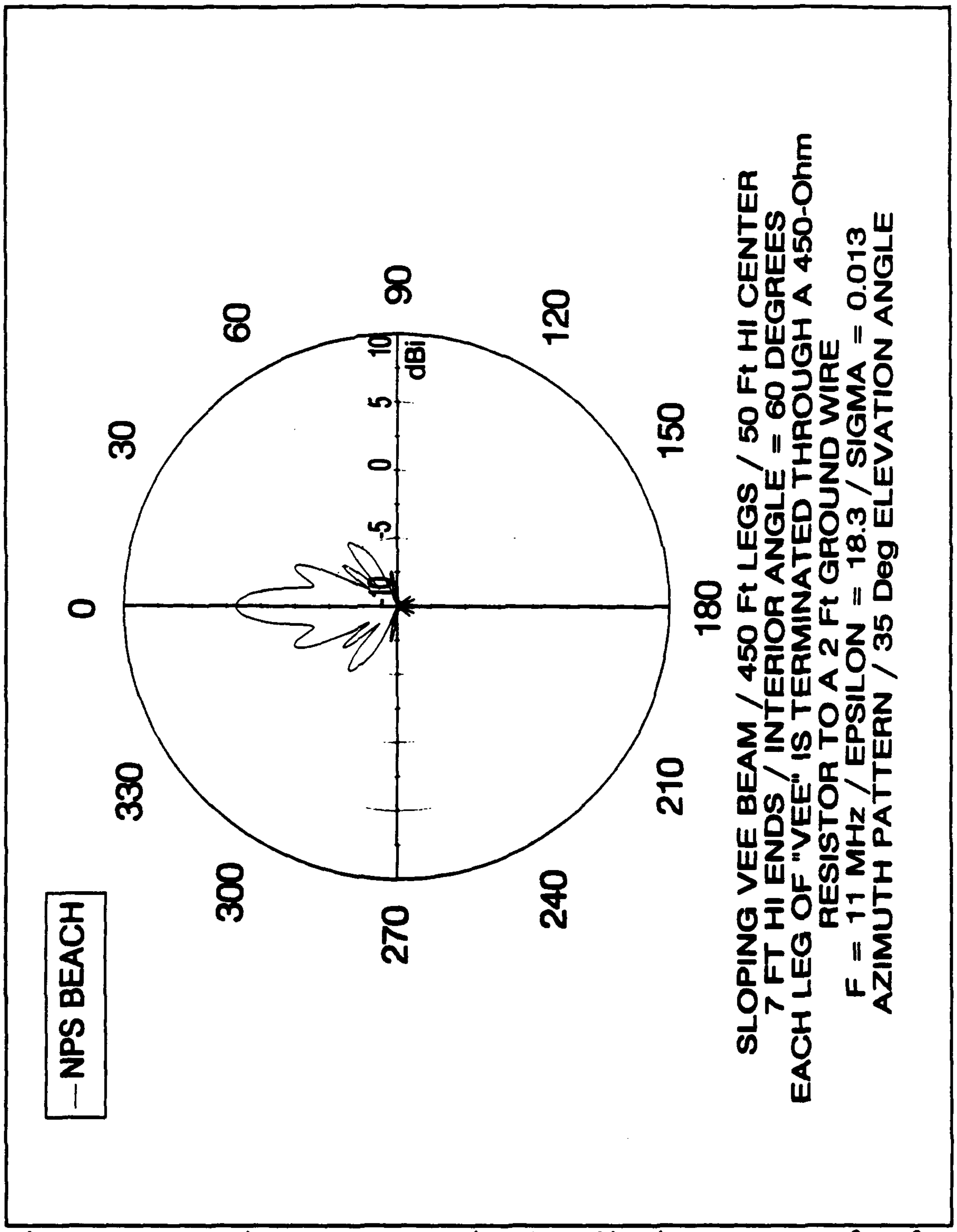

Figure 36. Sloping-Vee Beam Azimuth Radiation Pattern (θ=55°), over the NPS Beach Ground at 11 MHz.

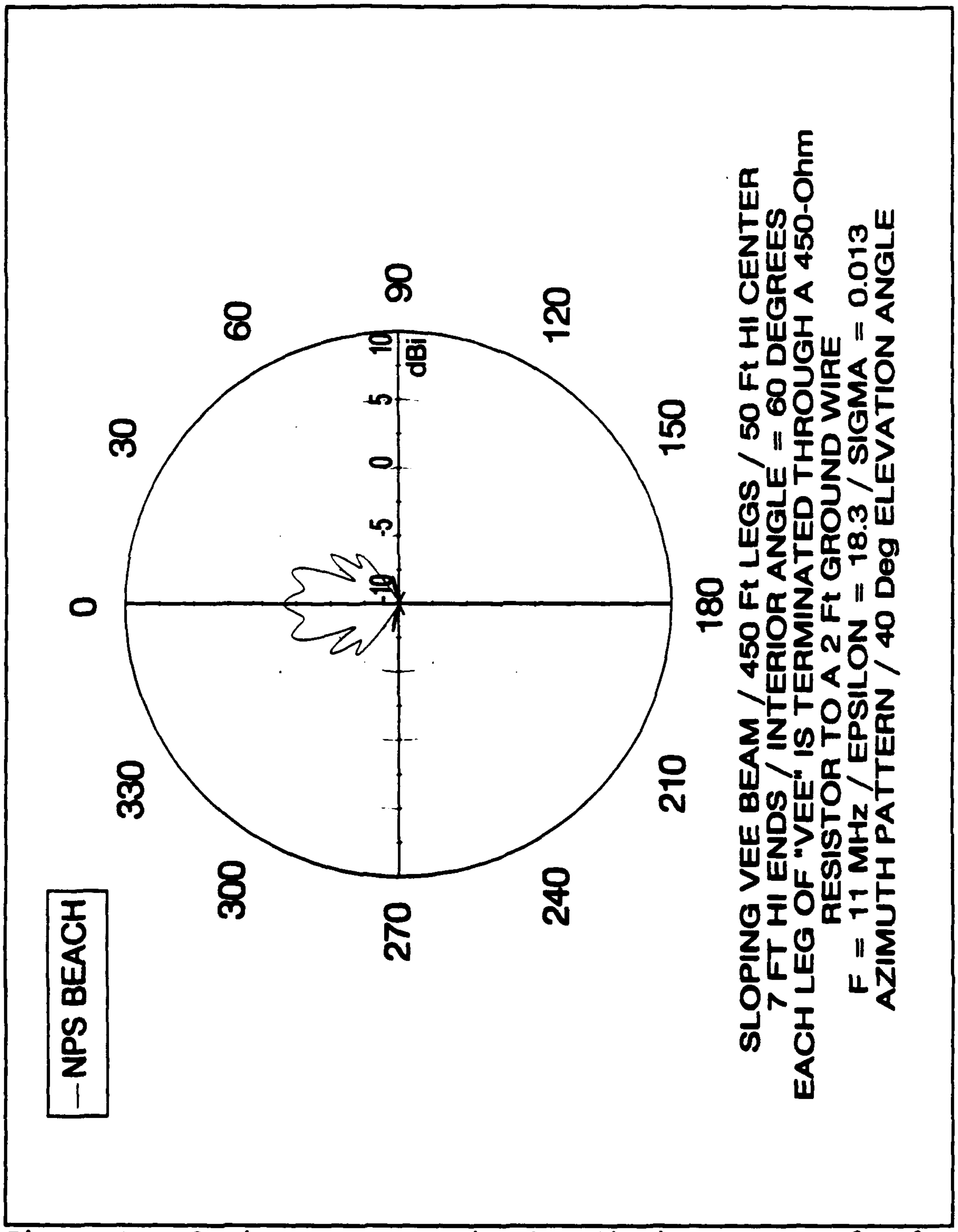

Figure 37. Sloping-Vee Beam Azimuth Radiation Pattern (θ=50°), over the NPS Beach Ground at 11 MHz.

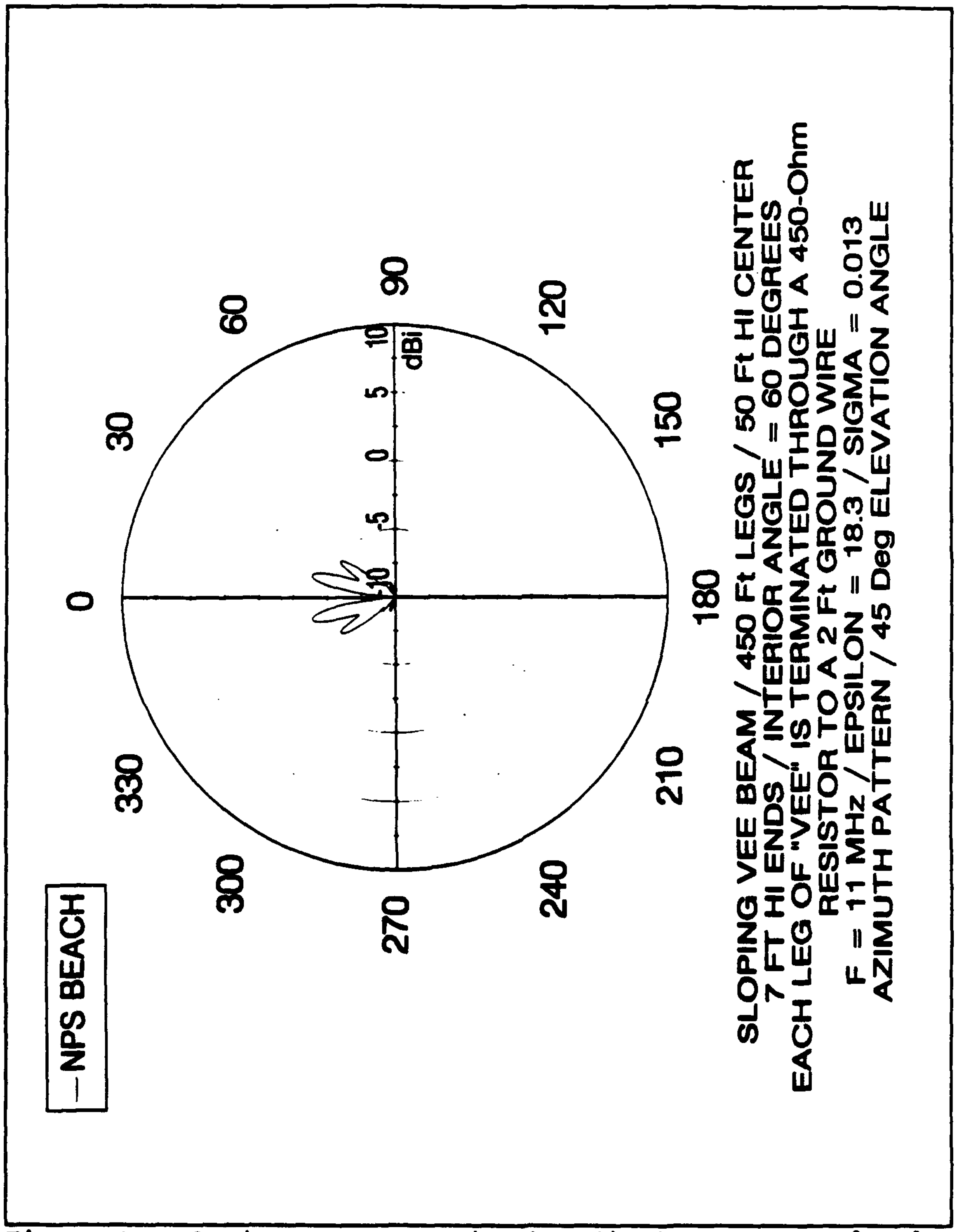

Figure 38. Sloping-Vee Beam Azimuth Radiation Pattern (θ=45°), over the NPS Beach Ground at 11 MHz.

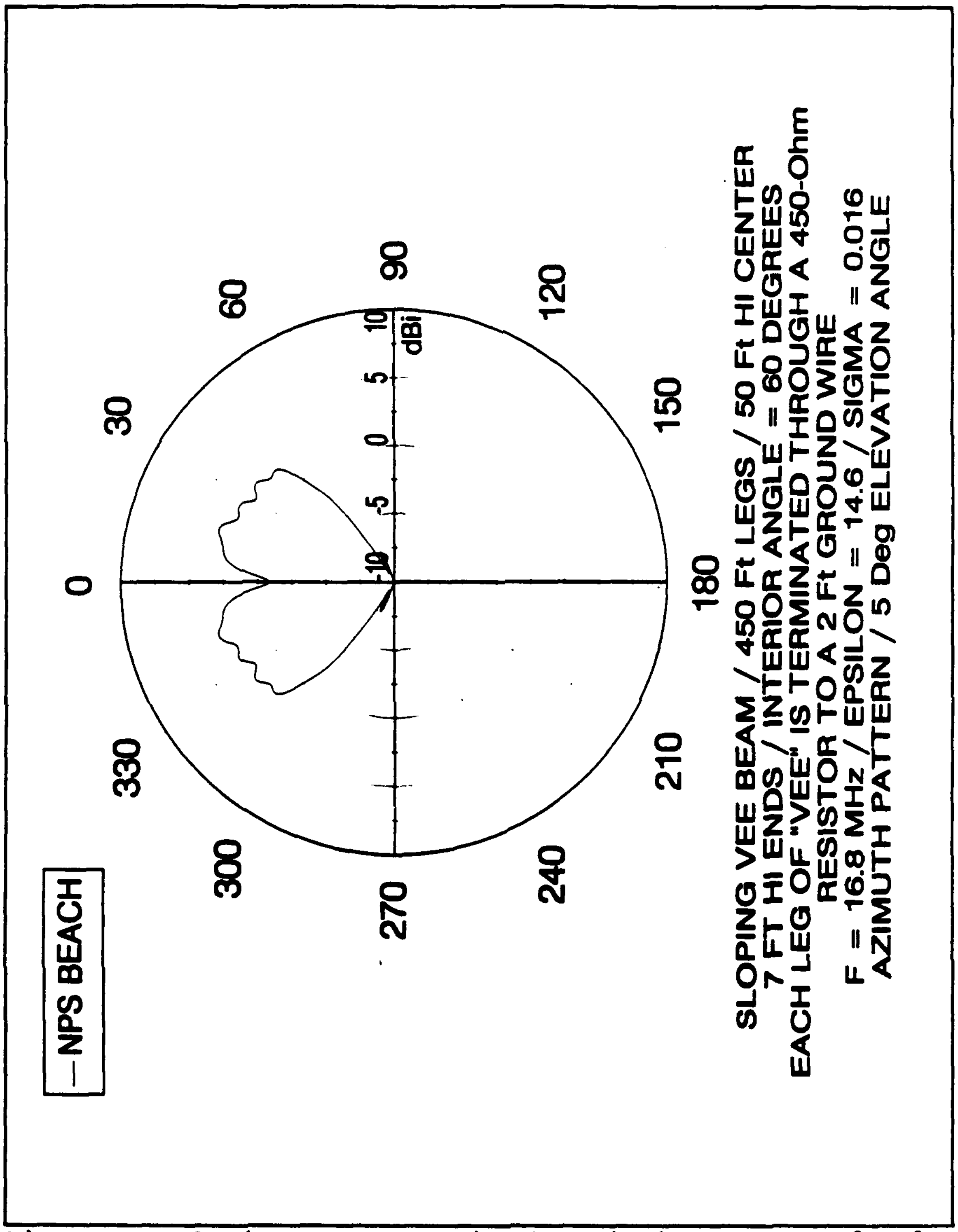

Figure 39. Sloping-Vee Beam Azimuth Radiation Pattern (θ=85°), over the NPS Beach Ground at 16.8 MHz.

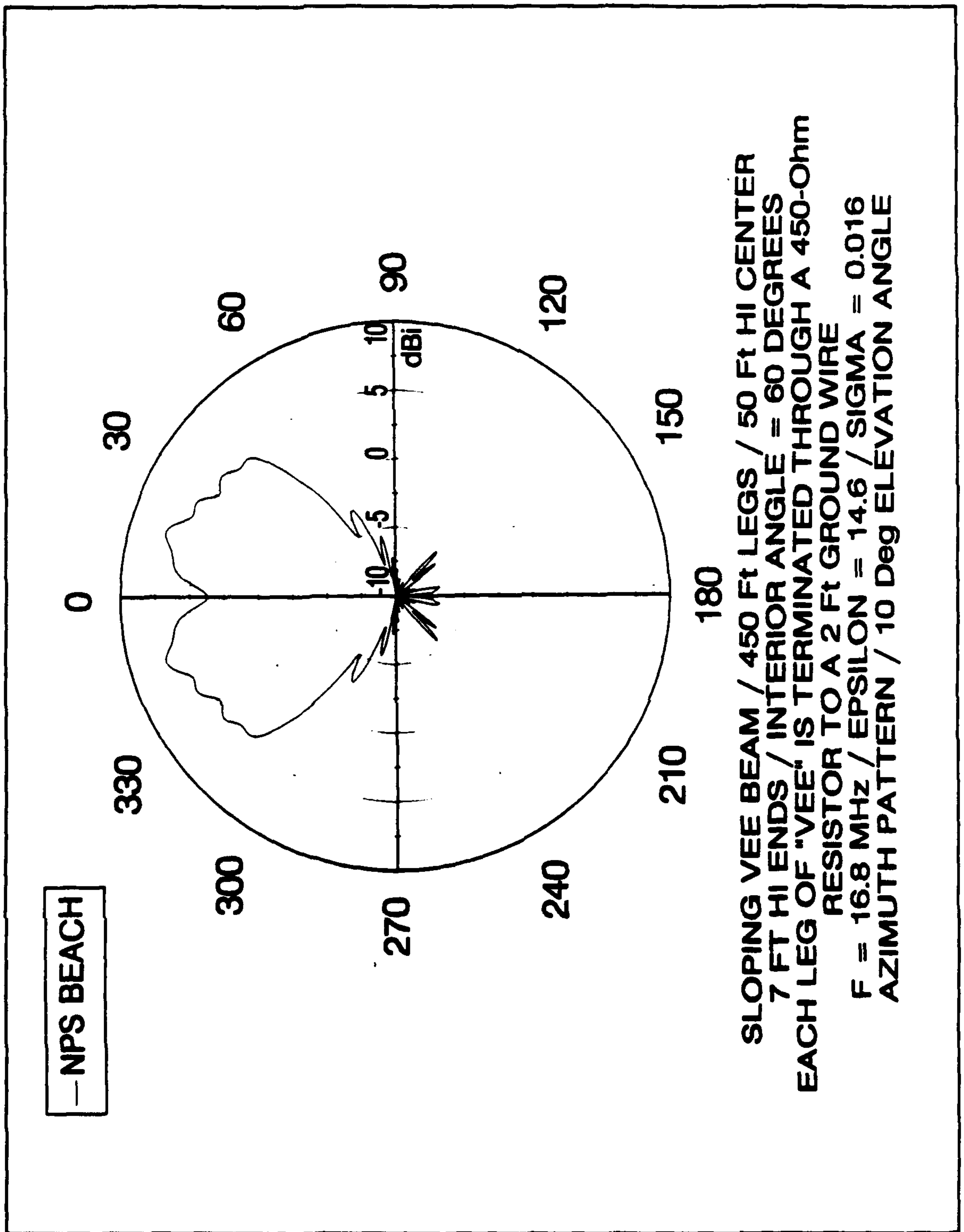

Figure 40. Sloping-Vee Beam Azimuth Radiation Pattern (θ=80°), over the NPS Beach Ground at 16.8 MHz.

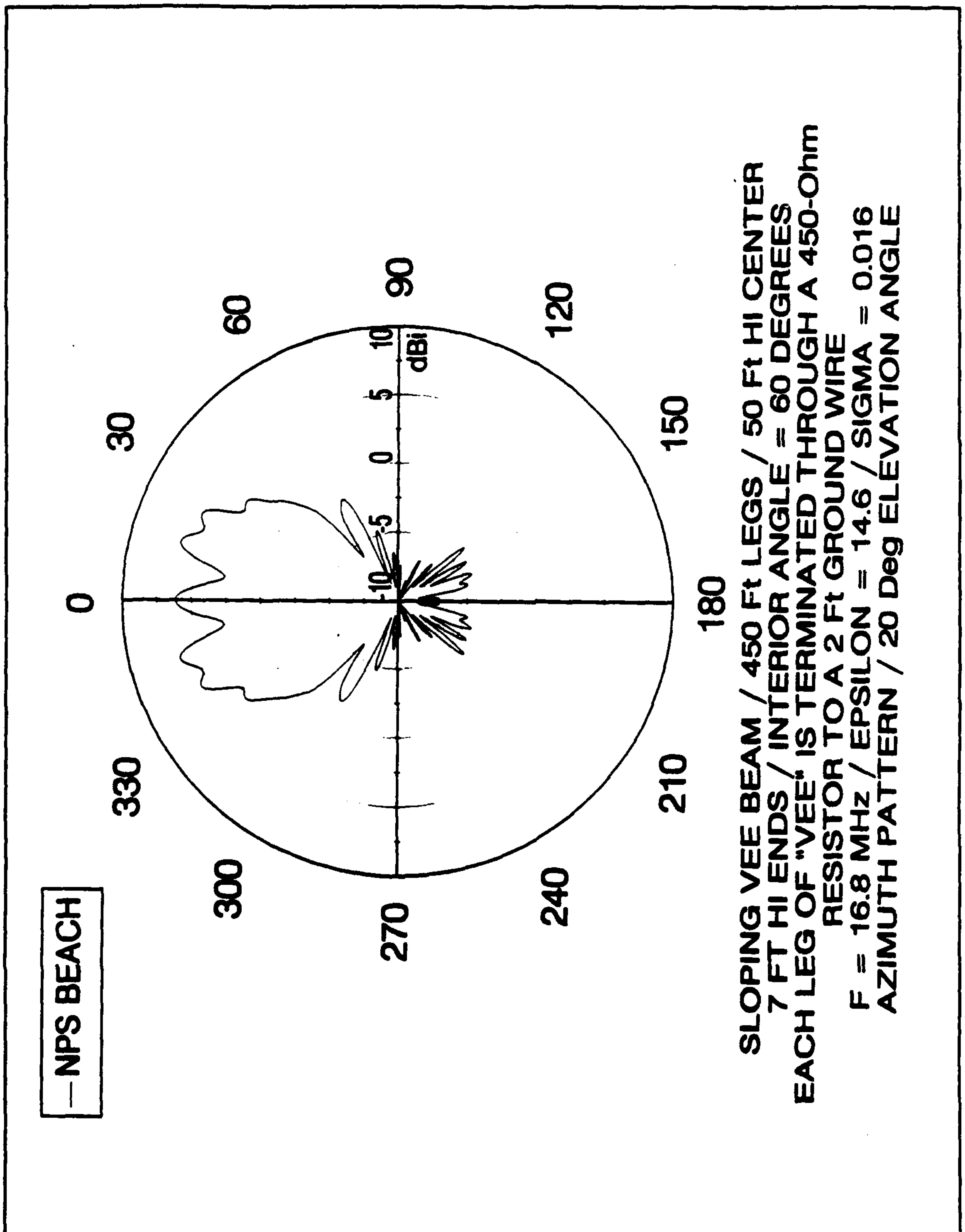

Figure 41. Sloping-Vee Beam Azimuth Radiation Pattern (θ=70°), over the NPS Beach Ground at 16.8 MHz.

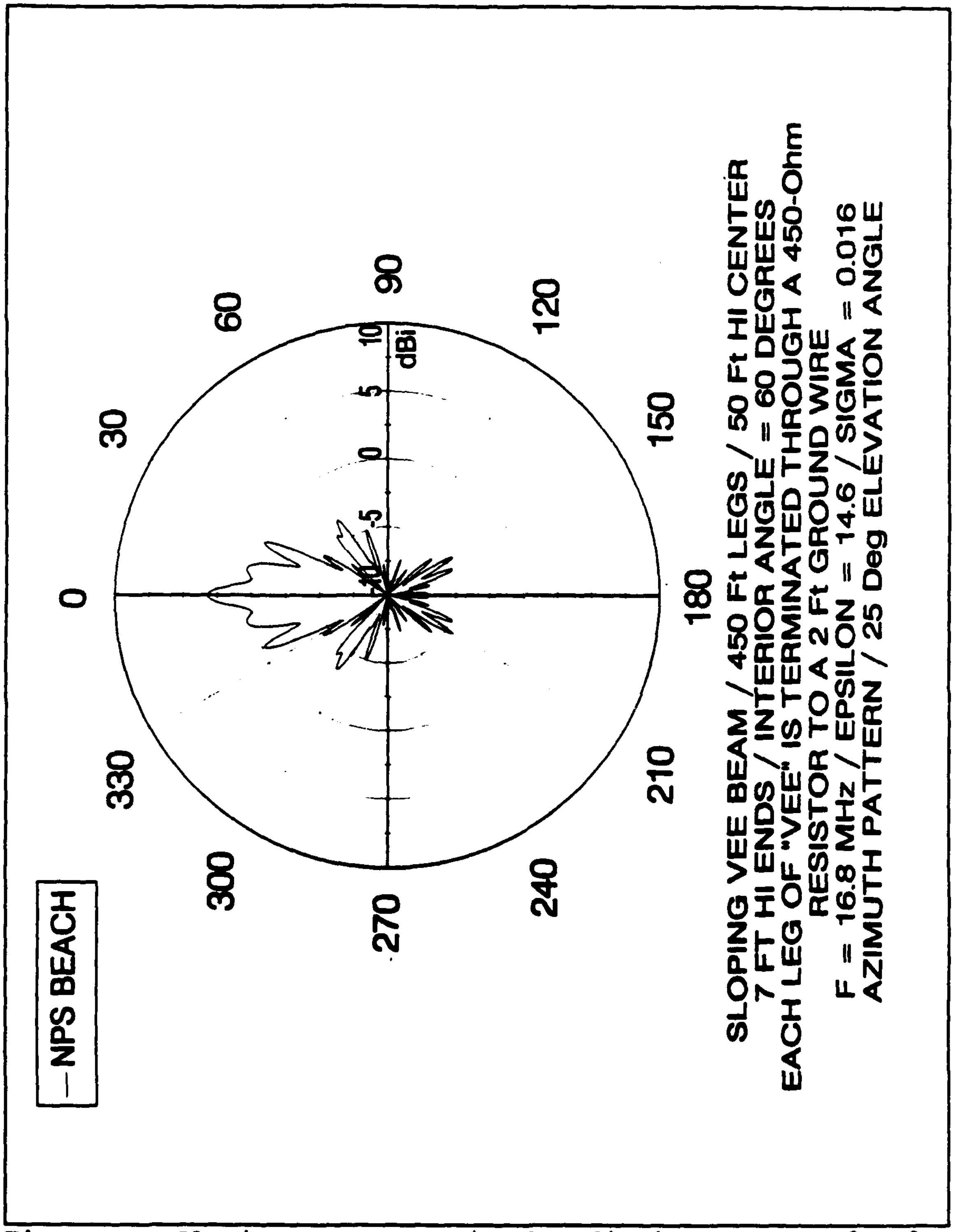

Figure 42. Sloping-Vee Beam Azimuth Radiation Pattern (θ=65°), over the NPS Beach Ground at 16.8 MHz.

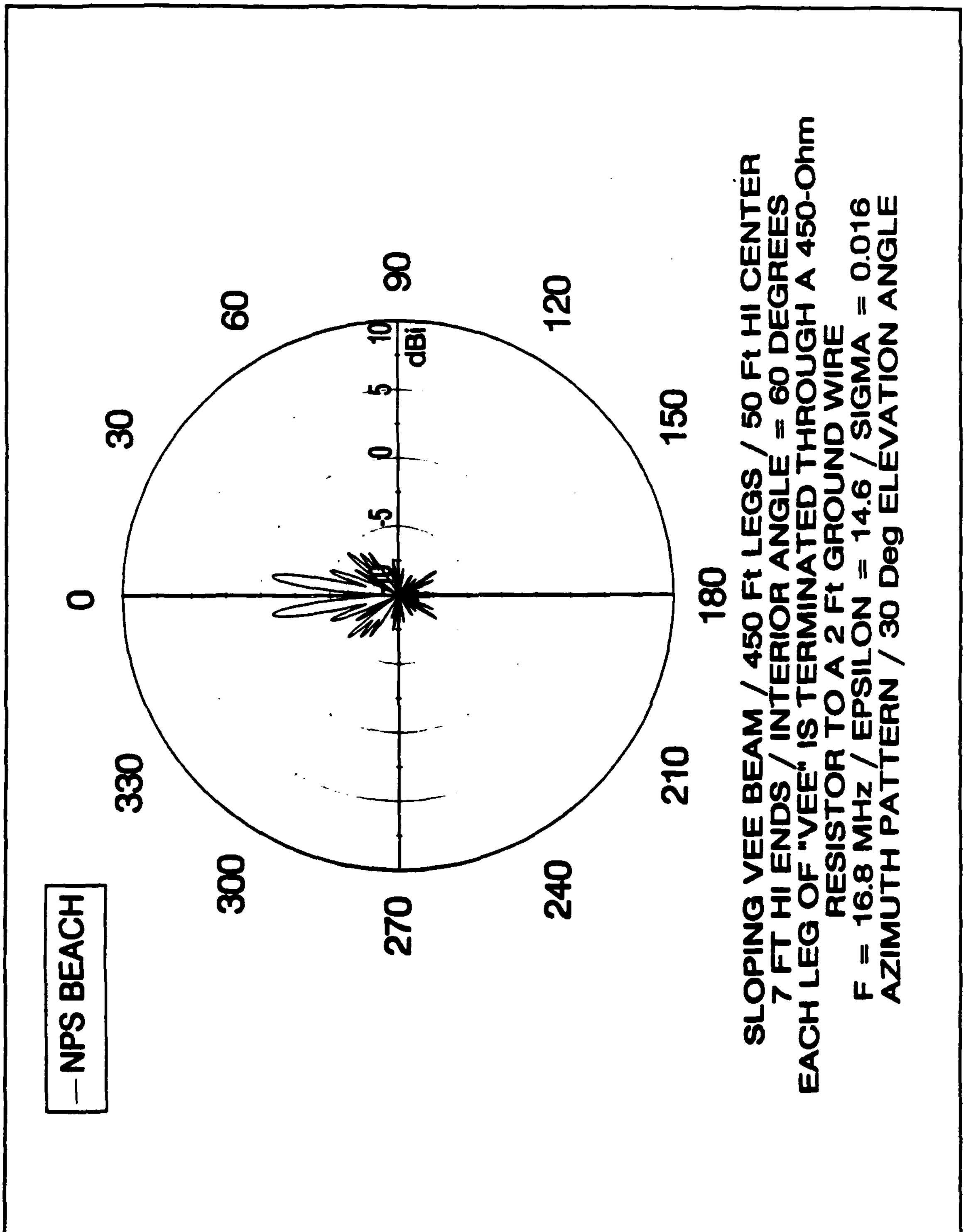

Figure 43. Sloping-Vee Beam Azimuth Radiation Pattern (θ=60°), over the NPS Beach Ground at 16.8 MHz.

LIST OF REFERENCES

1. Christinsin, A., "The AFWØNXX Longwire," *AFCS Frequency Management Digest,* April 1973.

2. Jenson, A. Edward, "The Effect of Antenna Geometry on Sloping Vee Radiation Patterns", *AFCS Frequency Management Digest,* April 1973.

3. Mission Research Corporation Report for period 1 July 1975 - 30 September 1975, *A Universal Impedance for Soils,* by C. L. Longmire, and K. S. Smith, Santa Barbara, CA, October 1975.

4. King, W. R. and Smith S. G.,*Antennas in Matter, Fundamentals, Theory and Applications,* MIT Pres, Cambridge, MA. 1980.

5. Smith S. G. and Norgard D. J., "Measurements of the Electrical Constitutive Parameters of Materials Using Antennas," *IEEE Transactions on Antennas and Propagation,* pg 783, July 1985.

6. *Ground Measurements Probe,* Communications Systems Division, Document No. 900-0036B, 1990.

7. Naval Ocean Systems Center, *The Numerical Electromagnetic Engineering Design System (NEEDS) - Version 2.0*, June 1989.

8. Cheng K. D., *Field and Wave Electromagnetics,* Addison - Wesley, 1989.

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